

Airline strategies' impact on gate occupancy at Schiphol airport

Analysis of summer season 2017

Final thesis

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Amsterdam, 29-06-2018

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Preface

This research report is used to graduate for the Bachelor of Science degree in Aviation Operations from the Amsterdam University of Applied sciences. During this bachelor a wide range of aviation related aspects including flight planning, the cooperation between all aviation stakeholders and process optimization are given. In this thesis all these aspects come together with a focus on capacity management.

For the opportunity of graduating at the KDC Mainport I would like to thank the KDC cooperation and its stakeholders LVNL, Schiphol and KLM. Special thanks for the LVNL for facilitating this research in their headquarters. Furthermore, this cooperation turned out to be very useful when research data was needed. The communication was experienced as smooth because when data was needed, it did not take longer than a week to receive. The LVNL data was provided via Ferdinand Dijkstra while Jeffrey Schäfer gave the needed data from Schiphol, I would like to thank both for their efforts.

During the process of graduating Frenchez Pietersz supported me with sharp remarks, feedback and humour. Thanks to him I learned new things while conducting my research. This is also the fact for me HvA thesis advisor, Paolo Scala who helped me in every way he could.

The scrum sessions turned out to be vital for me to execute the research. I would like to thank Alina Zelenevska for all her patience and support during those sessions, these helped me to achieve the best result. The bi-weekly sprint reviews also were of great importance thanks to Boudewijn Lievegoed, Coen Vlasblom and Evert Westerveld the research was kept within the vision of KDC Mainport.

During my time at the KDC Mainport I shared an office with Gijs Peters, Roel Wouters, Megan Heijke, Marc Eijkens and Bas Broekstra. Thanks to them it was a great period where we supported each other in every way possible, positively influencing our researches. Also, I would like to thank Huib de Jong for his help with the quantitative analysis.

This research is made using the ethical guidelines of the Amsterdam University of Applied Sciences. It is in no way meant to be harmful towards any person, company or organization. If any of the data in this report is used or referred to, written consent is required from the Knowledge and Development Centre Mainport Schiphol.

I wish you a pleasant reading.

MA Ringelberg

Amsterdam

29-06-2018

Abstract

Martijn Ringelberg, Aviation Operations, Amsterdam University of Applied Sciences Abstract of Graduation Thesis, submitted 29-06-2018:

Airline strategies' impact on gate occupancy

This research has been conducted in order to evaluate the impact of different airline business models on the gate occupancy and gate capacity at Amsterdam Airport Schiphol. This research has run from February till July 2018 as a graduation thesis for the Amsterdam University of Applied Sciences. Statistical data analysis of local Airport Collaborative Decision Making (A-CDM) data and interviews with several key stakeholders were the main research methods used. The data comprised of ground movements at AAS, including actual time of arrival, departure, in-block, off-block and scheduled time of in-block and off-block. This data was used for calculating the difference in scheduled and actual turnaround times to identify any correlation between airline business model impacts on the gate occupancy at Amsterdam Schiphol Airport. Against expectations the results showed there is only little correlation between airline business models and their turnaround time delay. Other findings included that a ground handler had a personnel shortage during flight movement peak hours and that the implementation of local A-CDM did not result in a better gate occupancy. It is recommended to review the gate planning process resulting in better use of available gate capacity.

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List of Abbreviations

A-CDM	=Airport Collaborative Decision Making
AAS	=Amsterdam Airport Schiphol
ACL	=Airport Coordination Limited (UK slot coordination)
AIBT	=Actual In-Block Time
AOBT	=Actual Off-Block Time
ATAT	=Actual Turnaround Time
ATFM	=Air Traffic Flow Management
CAPA	=Centre for Aviation
CIA	=Central Intelligence Agency
CISS	=Central Information System Schiphol
CT	=Connecting Time
CWC	=Carrier within a carrier
DLR	=German Aerospace Centre
EDD	=Electronic Data Display
EIBT	=Estimated In-Block Time
EOBT	=Estimated Off-Block Time
EU	=European Union
FAA	=Federal Aviation Agency
FLUKO	=Flughafenkoordination Deutschland (Slot coordination Germany)
FSNCs	=Full Service Carriers
HS	=Hub and Spoke (network)
IATA	=International Air Transport Association
KDC	=Knowledge Development Centre
LCCs	=Low Cost Carriers
LVNL	=Luchtverkeersleiding Nederland (Air Traffic Control the Netherlands)
MAC	=Mean Aerodynamic Cord
MaxCT	=Maximum Connecting Time
MCT	=Minimum Connecting Time
NABO	=Narrow Body aircraft

NLR	=Nederlands Lucht- en Ruimtevaart Laboratorium (Dutch Aerospace Center)
P2P	=Point-to-Point (network)
RAM	=Risk Assessment Matrix
RASAS	=Regulation Aircraft Stand Allocation Schiphol
SLA	=Service Level Agreement
SIBT	=Scheduled In-Block Time
SOBT	=Scheduled Off-Block Time
SOP	=Standard Operating Procedure
SOT	=Stand Occupancy Time
SQ	=Sub-(research) Question
STAT	=Scheduled Turnaround Time
TAT	=Turnaround time
TOBT	=Target Off-Block Time
TSAT	=Target Start-up Approval Time
USA	=United States of America
VOP	=Vliegtuig Opstel Plaats (Aircraft stand)
WIBO	=Wide Body aircraft
WRC	=Wave Repeat Cycle

Definitions of terms

Aircraft block time

The block time starts when an aircraft taxis into a stand and the wheel chocks, or blocks, are placed in front and behind one of the aircraft wheels. These function as a parking brake so the aircraft will not be able to move during the ground handling process. The Scheduled In-Block Time (SIBT) or Scheduled Off-Block Time (SOBT) is the same as the scheduled arrival or departure planned ahead by the airline. When an aircraft actually arrives at the gate the Actual In-Block Time (AIBT) is monitored, when actually departing the Actual Off-Block Time (AOBT) is monitored.

Actual In-Block Time, AIBT

Actual time where the aircraft blocks are applied to the gear.

Actual Off-Block Time, AOBT

Actual time where the aircraft blocks are removed from the gear.

Scheduled In-Block Time, SIBT

Scheduled time where the aircraft blocks are applied to the gear.

Scheduled Off-Block Time, SOBT

Scheduled time where the aircraft blocks are removed from the gear.

Target Off-Block Time, TOBT

Ground handler prediction of when the aircrafts' turnaround is completed.

Target Start-up Approval Time, TSAT

An air traffic control predicted time for when an aircraft is approved to start its engines.

KLM flight coordinator, KLM vlucu

KLM employee situated next to Schiphol gate planning department, providing more information about KLM and KLM partner flights if necessary

Mean Aerodynamic Cord, MAC

The MAC value represents the aircraft centre of gravity in relation to the cord of the aircraft centre wing (Flight Mechanic, sd). When the centre of gravity is not between the front or main gear, the aircraft tips on its tail and damages itself. Therefore, an aircraft has a defined MAC value range which should not be exceeded

PLUG ground handling application

At the moment the PLUG application is tested by a ground handling provider at Schiphol airport. This app enables all separate handling processes where the supervisor of the specific process can fill in when the process was started resulting in an earlier and better TOBT estimation

Summary

As described in ATM2020+, a capacity development report for the Dutch future aviation, Schiphol airport is expected to have an aircraft stand shortage. However, at the moment during summer season peak hours all gate stands are already occupied. Schiphol stakeholders have the feeling that the aircraft stands can be used more efficient as some airline business models tend to keep their aircraft at the gate longer than scheduled. This research is therefore conducted to analyse the impact of airline strategies on the gate occupancy at Schiphol airport. The following main research question is answered:

How do airline characteristics, ranging from business model differences to variation in actual procedures, affect AAS gate capacity?

To analyse the impact of airline business models multiple research methods are used. Literature research, a quantitative analysis and interviews with key stakeholders are used to identify the turnaround time delay and its impact on the gate occupancy of Schiphol airport. The summer season of 2017, running from 26th of March until 29th of October, timeframe is used as this was a period with much flight movements. 91 passenger airlines had scheduled operations at Schiphol airport during the timeframe and are categorized into multiple airline business models: Full Service Network Carriers (FSNC), Low Cost Carriers (LCC), holiday carriers, regional carriers and hybrid carriers. These business models have differences and commonalities on several aspects such as network type and aircraft traffic mix. This research is focused on the differences in gate occupancy, calculating the turnaround time delay of a specific airline business model.

Interviews are kept with ground handlers, the airport and airlines to validate the research findings of the quantitative analysis. The interviewees pointed out interesting aspects that, in their opinion, influence the turnaround time. These aspects include the KLM flight coordinator, the gate planning and the prediction of Target Off-Block Times (TOBT) by the ground handler

Datasets of both the LVNL and Schiphol are combined to research all turnarounds completed in summer season 2017. The LVNL data consisted of local Airport Collaborative Decision Making (A-CDM) data with turnaround related milestones such as actual and scheduled block times. After combining the datasets, 289,000 flight movements were left to research and resulted in the following conclusions:

- All narrow body aircraft at Schiphol have a longer actual turnaround time of 9-12 minutes compared to the scheduled turnaround time while wide body aircraft have a difference of 8-16 minutes. As the airport gate planning uses the scheduled arrival and departure times, the gate occupancy is constantly higher than expected causing congestion at the airport.
- Turnaround are delayed for multiple reasons such as late passengers or non-boarding passengers of which their bags have to be removed from the aircraft. No correlation is found between airline business models. Also, during the interviews it was stated that a ground handler has a personnel shortage during the flight movement peak hours at Schiphol.
- The implementation of local A-CDM did not result in a better gate occupancy as it occurs that aircraft wait for their Target Start-up Approval Time (TSAT) at the gate.

Based on above mentioned research leading to the conclusions, three recommendations are drawn.

1. Implement predicted block times in gate planning system, keeping in mind historic data, weather, number of passengers, etc.
2. Expand the role of the KLM flight coordinator by involving more airlines than just KLM and its partners
3. Implement innovative solutions for more information and better communication during aircraft turnarounds.

Implementing these recommendations will create a more robust gate planning resulting in more efficient use of available gate capacity at Schiphol airport.

1 Introduction

Over 100 different airlines operate at Schiphol airport, this implies to have hundreds of aircraft undergoing turnaround operations, carried out by several ground handling service companies. In order to have smooth turnaround operations, it is crucial to achieve on-time performance. This requires efficient scheduling and planning activities for stakeholders like Amsterdam Airport Schiphol (AAS), KLM and the Dutch air traffic control (LVNL). Turnaround operations begin when an aircraft is on-blocks at its assigned gate, beforehand a planning is made which predicts the Estimated In-Blocks Time (EIBT) based on schedule, flight time and predicted landing and taxi-times. During the turnaround all needed services for the airline are carried out by the ground handlers such as (de-)boarding, cleaning, catering etc. While turnaround operations are conducted, the ground handler continuously updates the Target Off-Blocks Time (TOBT) for the departing flight of the airline. When all passengers are aboard and services have all finished, the pilot of the aircraft notifies to the LVNL that it is ready to depart, when the LVNL reads back that they are allowed to leave the aircraft goes off-blocks and departs from the gate.

Between the carriers operating at Schiphol airport there are a lot of differences in characteristics and ways of operating. KLM for example is a Full Service Network Carrier (FSNC) and primarily operates on connecting flights. EasyJet on the contrary, is a Low Cost Carrier (LCC) with only point-to-point passengers and a dedicated low cost terminal at the H-pier of Schiphol. Other airline business models include TUI NL (holiday), Norwegian (hybrid) and Flybe (regional). The turnaround procedures also differ per airline, depending on aircraft type, type of passenger and security classification of the destination.

There are various possible reasons for an actual turnaround to take longer than scheduled. Often an aircraft arrives at Schiphol earlier than scheduled, meaning it needs a gate earlier than planned. Also during the turnaround, processes could be delayed by for example mechanical failures or inefficiencies caused by any stakeholder.

As stated in ATM 2020+, a document about capacity development at Mainport Schiphol, more This research aims to investigate the impact of the different airline business models operating at Schiphol on the gate occupancy.

1.1 Airline business models

All airlines operating flights to and from Schiphol airport have their own way of operating their flights and company for multiple reasons. The airline industry is a dynamic and highly competitive business environment where, on the one hand, passengers have various needs and desires, and on the other hand, airlines who are the entities that should satisfy passengers needs and desires delivering a good journey experience to them. In general, there are 6 airline business models:

- Full Service Network Carrier (FSNC)
- Low Cost Carrier (LCC)
- Holiday carriers 'Charter'
- Regional carriers
- Freighter carriers
 - Full
 - Combination with FSNC
- Hybrid carrier Combination of multiple business models

All business models differ on aspects like aircraft traffic mix, aircraft utilisation, route network and strategic alliances. For example, EasyJet, classified as a LCC, has scheduled turnaround times at Schiphol of 35 minutes while KLM, classified as FSNC, mostly schedules at least 60 minutes for an aircraft of the same size. Furthermore, FSNC deploy a different route network by making use of hubs and let passengers transfer at their hubs to get to their destination while LCC have point-to-point routes where passengers fly directly to their destination.

1.2 Current gate planning process

For making efficient use of all gates at Schiphol possible, all turnarounds are planned well in advance. About 2-5 years in advance seasonal plans are made to have an overview of how much turnarounds there will be in the future and which traffic mix is most likely to be operated. From 2

years in advance a detailed planning is made to identify possible schedule collisions in combination with the total amount of aircraft stands. On a day-by-day basis, Schiphol manages the gate planning by constantly updating aircraft schedules and make gate changes if an aircraft is delayed or arrives earlier. This operational gate planner is situated next to a flight coordinator of KLM (Dutch: Vlucó), this KLM employee ensures that effective communication is held between the largest airline, its alliance members and the airport.

For assigning gates to all airlines operating to and from Schiphol airport a policy has been made by AAS. This policy is contained in the Regulation Aircraft Stand Allocation Schiphol (RASAS) and it includes the basic principles used for the daily gate and bus planning at the airport (AAS, 2016). A total of 19 policy principles make sure that all flight movements are scheduled efficiently. These policies include for example that airlines carrying many transfer passengers are assigned to gates with the objective to reduce walking distances, while airlines that carry few or none transfer passengers will be planned outside the central transfer zone. To obtain a robust planning that only needs limited changes there is a 20-minute buffer between two flights at a gate. Furthermore a 'best fit' system is in place, making sure that the size of the aircraft should perfectly match the size of the aircraft stand. Also if a narrow- or wide body aircraft has a turnaround time of respectively 210 or 170 minutes, it will be instructed to tow the aircraft to another (remote) stand.

1.3 Aircraft turnaround process

During the turnaround operations stakeholders work together, making sure that it will undergo all the necessary operations before departing according to the schedule. In figure 1 a schematic description of the turnaround operations can be seen.

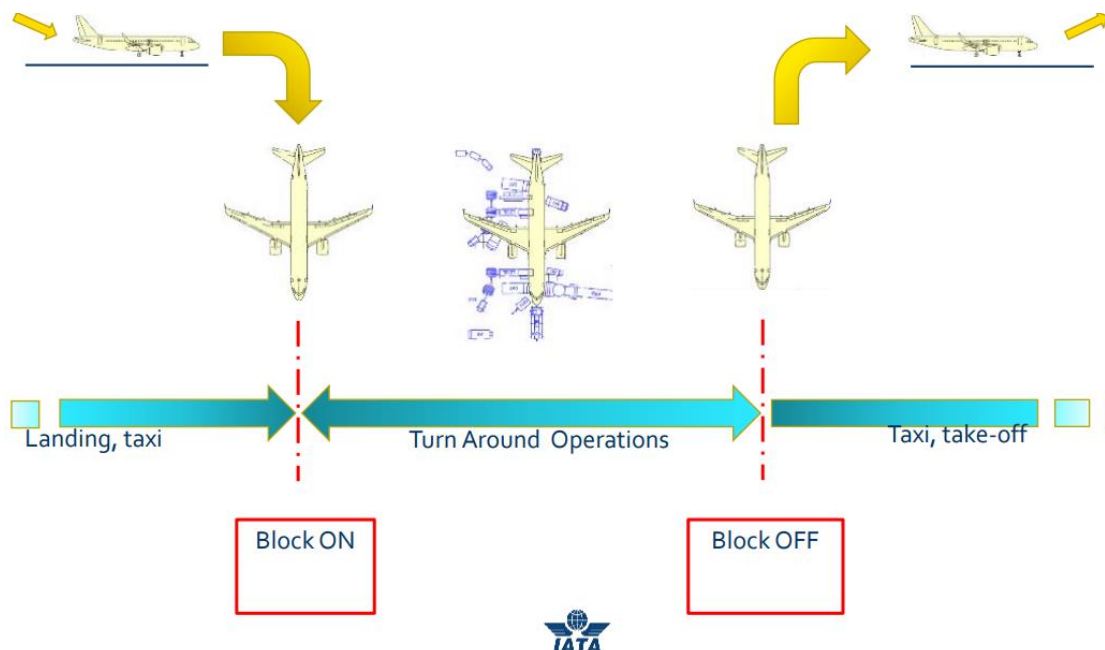


Figure 1, turnaround process (IATA, 2017).

The necessary amount of time for turnaround operations can vary per airline or ground handler as they have their own unique procedures. At Schiphol there are 5 main ground handlers: KLM ground services, Swissport, Aviapartner, Menzies and Dnata. Each of these ground handlers have a different Service Level Agreement (SLA) with their customers, ensuring that the turnaround is conducted according the airlines' service level. This agreement contains the complete turnaround process of the airline, including rules for conducting all turnaround operations and penalties in the case that these rules are not respected. For various reasons a turnaround can take longer or shorter than expected, if the aircraft has a low load factor, meaning having a small amount of passengers on board, this could save time during boarding and de-boarding. Moreover, airlines can deliberately let an aircraft stay at the gate for a longer period to make sure that connecting passenger(s) will be on the flight.

1.4 Problem statement

Schiphol airport is reaching its limit of 500,000 flight movements per year. Before reaching this amount of movements several capacity constraints have already been tackled, for example by building the Uniform-platform that created five extra remote stands. Over 90 passenger airlines have scheduled flights operating from and to Schiphol. All these airlines have a wide variety of operating their flights, figure 2 shows these varieties categorized in three subjects.

The figure gives an overview of differences between passenger airline strategies on three levels: airline business model, airline characteristics and flight specific characteristics. 5 Different airline business models have been identified and categorized from wide to specific differences. Each airlines, depending on its business model, has their own characteristics such as: traffic mix, type of ground handler and passenger type. Each of these differences may result in a difference in gate occupancy which may cause gate capacity congestion. Besides there are a range of differences per flight such as the airline procedures, the used cost index (flying faster or slower) and the SLA between ground handler and airline (Boekhout, 2018). Schiphol airport accommodates over 90 passenger airlines with different strategies. It can be deduced that the gate capacity can be potentially affected. In this thesis, the impact of airline strategies on gate capacity is researched by conducting a data-driven analysis.

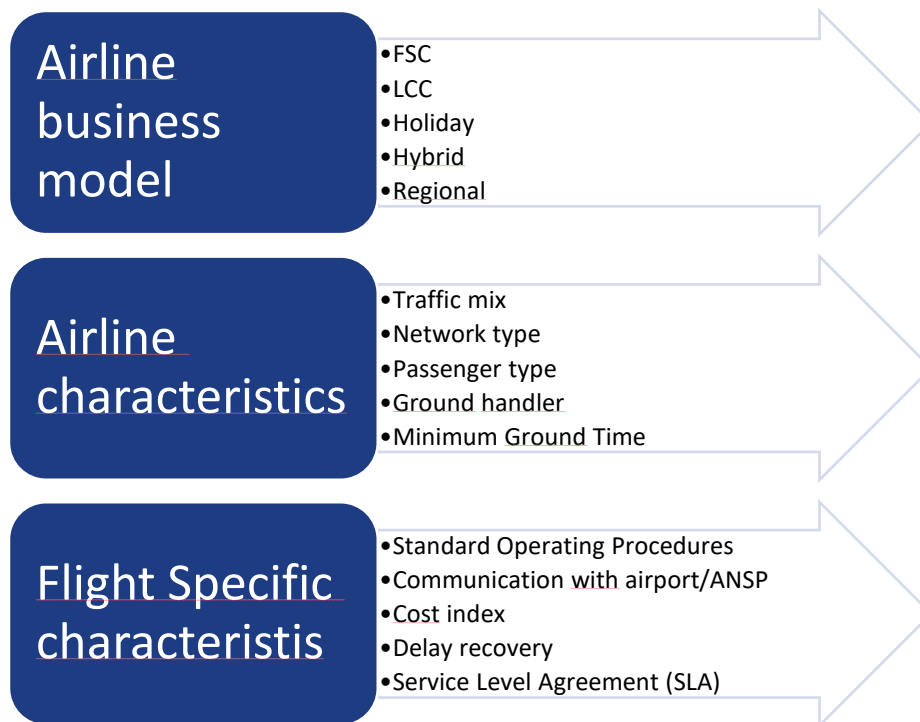


Figure 2, visualization of airline difference examples.

1.5 Research objectives

The research objectives are as follows:

- To analyse what the impact is of different airline business models and airline traffic mix on the gate capacity of AAS.
- To research what the impact of different airline strategies is on the airside capacity of AAS.
- To identify coping mechanisms to capacity-related challenges resulting from airline policies.

This research will be in line with the KDC objectives as the recommendations will contain valuable and innovative solutions for all stakeholders to create sustainable development at AAS.

1.6 Research relevance/significance

As AAS is growing every year, more and more capacity problems arise affecting the daily operations of all operators. These problems can have a substantial impact on, for example the

amount of delays which is an indicator of the stability of the schedule of all airlines at the airport. More research into the subject of correlation between airline strategies and airport capacity is needed to tackle the capacity issues. This research will result in a better understanding of airline strategies operating at AAS, which in turn could lead to a number of gate capacity improvements.

The conclusions and recommendations of this research will be in favour of the airport, the aircraft operators and the air traffic control. Possible improvements would be lowering the amount of turnaround delays, better planning of resources and a more robust gate planning. These key areas are important for every stakeholder involved in the operation of AAS.

1.7 Research Questions

1.7.1 Main research question

How do airline characteristics, ranging from business model differences to variation in actual procedures, affect AAS gate capacity?

1.7.2 Sub research questions

1. What are the strategy differences between airlines operating at AAS?
2. What is the impact of airline structures and airline traffic mix on gate occupancy of AAS?
3. What delay recovery techniques are used by airlines at AAS and what is their impact on the airside capacity of AAS?

1.7.3 Background questions

Ordered per sub-research question:

1. What are the different airline strategies operated by the airlines currently operating at AAS?
What are the strategy differences between airlines?
What is the average turnaround time?
2. What is the average turnaround time delay at AAS per airline business model?
What is the average turnaround time delay at AAS per airport pier?
3. What are the drivers and incentives for an airline to be on time at AAS?
How are slots divided in the Netherlands?

1.8 Research scope

A clear boundary for this project is that only the effect on the gate capacity of Schiphol will be taken into account. The literature research will contain limited information about surrounding airports to compare some Key Performance Indicators (KPIs) however, no quantitative data of surrounding airports is investigated during the research.

The objectives state that the differences per airline strategy and their impact on the gate capacity of AAS will be analysed and that a set of recommendations will be concluded on how to cope with the capacity impacts. The airline characteristics will be researched according to figure 2 on previous page. The business model differences are mainly found in literature and have been researched extensively; the literature review will give a good impression of the business model differences and how they emerged over the years. The various airline characteristics are more specific, meaning that exact numbers can be withdrawn from data. When combining the literature and actual data a relation can be made on the impact of different airline strategies on the capacity of AAS.

Furthermore, this research will focus on improving the gate capacity at Schiphol airport by calculating the gate occupancy per airline business model. By conducting interviews to various airport stakeholders, potential explanations can be given to the data collected and potential recommendations for improving aircraft turnaround time can be suggested.

1.9 Thesis structure

This report is composed by eight chapters, including this introduction chapter. Furthermore, chapter 2 will contain the research methodology showing how the analysis has been conducted. The review of the literature is discussed in chapter 3, containing relevant information gained from

sources related to the subject of airline business models and gate occupancy. Chapter 4 elaborates on the research methodology, showing which steps have been taken to find answers on all research questions. This chapter also contains the results of the interviews kept as these give a good introduction to the findings. These findings are shown in chapter 5 using multiple figures that create a visualization of what the impact is of airline business models on the gate occupancy at Schiphol airport. Afterwards, all research findings are concluded in chapter 6 including the literature research, quantitative analysis and interviews. The interpretation of all results and conclusions are mentioned in chapter 7 while chapter 8 will contain all recommendations made to the Schiphol stakeholders for improving the gate capacity.

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2 Methodology

Quantitative and qualitative data is researched and combined to create a thorough research on the airline business model differences in gate occupancy at Schiphol airport. The research design and hypotheses discuss how the research is conducted and what the expected outcome was. All other paragraphs discuss how data is gained, researched and how research findings will be visualized.

2.1 Research Design

In this section the way in which the research have been conducted is explained using the 'research onion' approach. The research onion approach is depicted in Figure 3, it includes the following processes (Saunders, Lewis, & Thornhill, 2016):

1. The research philosophies
2. The research approaches
3. Methodological choices for the research
4. The research strategies
5. The time horizons within the research
6. All techniques and procedures for the research

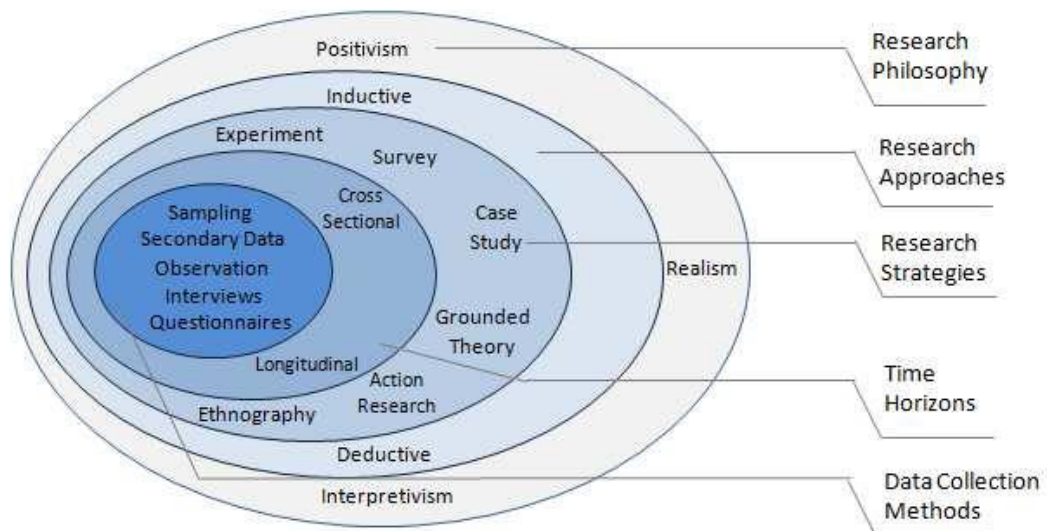


Figure 3, the research onion (Saunders, Lewis, & Thornhill, 2016).

An interpretivism philosophy is used for the development of knowledge throughout the entire project, meaning that human interests will be integrated into the research by using interviews. These interviews will contain observations and opinions of people from different points of views with regards to gate occupancy, turnaround process or airline business models.

In finding the impact of different airline business models on the gate occupancy a lot of data should be collected, various business models have to be identified and quantitative data has to be researched to find out what the exact gate occupancy is. Therefore, an inductive approach is used for this project. This means that data will be collected and researched, based on this data a theory will be built based on differences between airline business models and their gate occupancy.

Because both qualitative and quantitative data is used, the project has a mixed-method research method. The three sub questions mentioned in paragraph 1.7.2 break down the complete research. For some research questions only qualitative sources are used, for other questions both qualitative and quantitative sources are used. Therefore the research method is mixed, both quantitative data and interviews are used in order to carry out the analysis.

This research is conducted with a cross-sectional timeframe because the quantitative data refers to a specific period, specified in paragraph 2.4. This timeframe is used because it is applicable for daily operations at Schiphol airport.

2.2 Research Hypotheses

As further specified in the literature research chapter, there are differences between airline business models. FSNC carry much more transfer passengers and focus on these passengers as it is key for those passengers to catch their connecting flight at the airport. Because there is such a focus on this type of passenger it is expected that FSNC on average will stay longer at the gate than scheduled, enabling transfer passengers to board the aircraft. On the contrary LCCs and hybrid carriers are expected to be strict on their scheduled turnaround times as the aircraft usage of those carriers is significantly higher than other carriers (Budd & Ison, 2017). Regional carriers usually fly with smaller aircraft and low turnaround times, therefore it is expected that those carriers also have only a small difference between scheduled and actual turnaround times. Holiday carriers share operational similarities with LCCs as they too have a universal fleet type and operate as much flight hours per day as possible (Budd & Ison, 2017).

2.3 Research instruments

Three main research instruments are used for researching the impact of airline business models on the gate occupancy at Schiphol airport. Literature research, Quantitative data and interview data is combined so that the literature and interviews can validate the results of the quantitative data. The quantitative data used for this research contained the flight movements during summer season 2017, which ran between 26th of March 2017 and 29th of October 2017 according to IATA (IATA, 2017). For calculating the scheduled and actual gate occupancy the difference in scheduled and actual turnaround times are calculated. All interviews held during the research conducted between the 5th of February 2018 until the 11th of June 2018.

2.3.1 Quantitative data

Only turnaround times are taken into account for calculating the gate occupancy time, displayed in figure 4 below. The difference between SIBT and SOBT gives the scheduled turnaround, this is the time the airline scheduled between flights for the ground handling to take place. The time between AIBT and AOBT is the actual turnaround, this time shows how long the ground handling actually took.

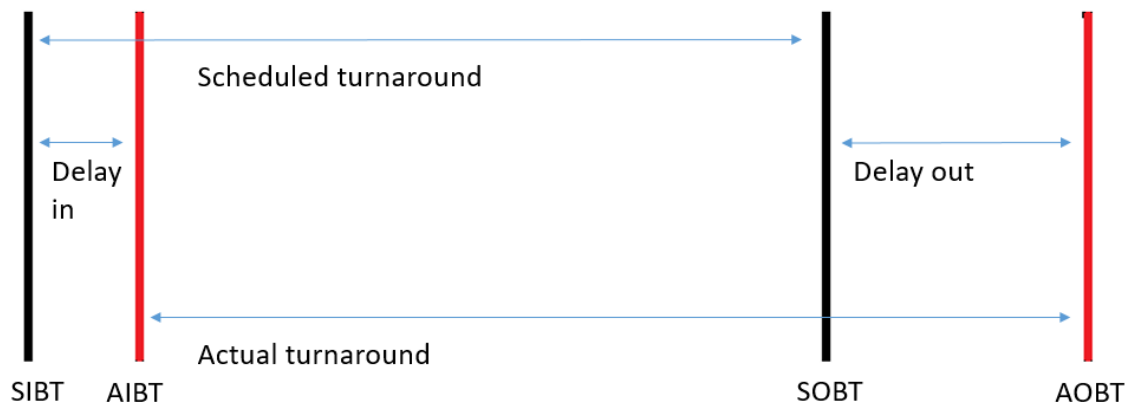


Figure 4, Difference in scheduled and actual block times.

As can be derived from figure 4 above the in- or outgoing delays will not be considered in the analysis. Only the difference between scheduled and actual turnaround will be considered as that will give the exact gate occupancy time.

Airport Collaborative Decision Making (A-CDM) data is used as quantitative data and is available from the LVNL database. This data constantly monitors all A-CDM milestones such as EIBT and EOBT. As can be seen in table 1 it contains the following values. An example of the LVNL dataset structure can be found in appendix III.

Table 1, LVNL dataset.

Data name	Description	Remarks
Time	A-CDM timestamp	Timestamp generated by A-CDM system, same as ATD or ATA.
ACID	Aircraft identification	Showing which airline operated the flight.
Reg	Aircraft registration	
Adep	Departure airport	Based on ICAO
Dest	Destination airport	Based on ICAO
Actyp	Aircraft type	International standard codes
Wtc	Wake turbulence category	According ICAO standard
SOBT	Scheduled Off-Block Time	
EIBT	Estimated In-Block Time	
ATD	Actual Time of Departure	
ATA	Actual Time of Arrival	
AOBT	Actual Off-Block Time	
AIBT	Actual In-Block Time	
DepGnr	Departure gate number	
ArrGnr	Arrival gate number	

The scheduled in-block time is not one of the A-CDM milestones and therefore not generated in the data. Because this time is needed for calculating the scheduled turnaround time, Schiphol is asked to provide the SIBT of all flight movements. As shown in table 2, Schiphol data will include the following values. An example of the Schiphol dataset structure can be found in appendix IV.

Table 2, Schiphol dataset.

Data name	Description	Remarks
ARRDATE	Date flight movement	
SIBT	Scheduled In-Block Time	
FLTNR	Flight number	
CALLSIGN	Aircraft call sign	
Kolom1	Three digit ICAO airline identification code	
ACREG	Aircraft registration	
ACTYP	Aircraft type	International standard codes
Airline		
Handler_PAX	Ground handler of the turnaround	
Datum	Date	

For analysing the data a number of predefined categorizations are needed to classify aircraft type, flight duration, arriving or destination airport and airline characteristics. These categorization are needed for displaying the results in a correct way and will be based on the following aspects:

- Aircraft type
 - Narrow body/Wide body (NABO/WIBO)
 - Wake turbulence category based on RECAT-EU
- Flight duration
 - Short-, medium- or long haul
- Arriving or destination airport
 - Schengen/Non-Schengen
- Airline characteristics
 - Business model
 - Ground handler of turnaround

The differentiation in aircraft type is made because larger aircraft have longer turnaround times and thus a higher gate occupancy, the wake turbulence category contains more categories and will therefore be used in combination with the aircraft fuselage width. In appendix IX the RECAT-EU wake turbulence category can be found, this categorization is also subject of another KDC study on the benefits for Schiphol (NLR, 2016).

The categorization for arriving and departing flight durations is divided into three categories; short-, medium- and long haul. There is no specified breakdown of flight duration, therefore a table is created which shows the flight duration in hours and total flight distance based on literature and own experience.

Within the passenger terminal at Schiphol airport there are some differences between services for Schengen and Non-Schengen passengers, because of the extra precautions the ground operations could take longer. Passengers arriving from Non-Schengen countries have to be checked carefully by customs and immigration personnel (Immigratie- en Naturalisatiedienst, 2018)⁴.

This research focuses on the impact of airline business models on the gate occupancy at Schiphol, therefore the airlines are categorised into business models. To categorize all airlines, the different airline business models are identified in the literature review. Moreover, the data is categorized based on which ground handler provides ground services for the airline as this could influence the turnaround times.

2.3.2 Interviews

As the quantitative data might not contain all the answers needed for this research, 5-10 employees working for the key stakeholders at Schiphol airport will be interviewed. They will be asked five questions in order to get a better understanding of backgrounds and to learn more on different views on Schiphol gate capacity and delay management measures of their company. Afterwards both data sources will be combined and it is expected that the interviews will validate the results. The five questions are listed below:

1. How do you experience the gate capacity problem at Schiphol?
 - a. Are there impacts (both positive and negative) on your operation?
2. Are aircraft or your airline/customer delayed at the gate for other than ATC/airport related delays?
 - a. For which reasons?
3. Which delay management measures/procedures does your airline/company use?
4. Which delay recovery measures does your airline/company use?
5. What is in your opinion the biggest issue with the gate capacity?

Above questions should give a clear view on how the interviewee experiences the gate capacity problem at Schiphol. This question is deliberately made very open to make sure the interviewee is not pushed in a certain direction. Questions 2, 3 and 4 focus on the cause of delay and delay management procedures of their company. By asking these questions it should be made clear what possible delay reasons there are for aircraft occupying the gate longer than scheduled. The last question wraps up the interview and it is expected that at the end of the interview, the interviewee provides a statement on what the biggest issue is with the gate capacity at Schiphol airport.

The interviews will be unstructured meaning that before an interview there is no planned sequence of questions to be asked to the interviewee (Sekaran & Bougie, 2016). Therefore, the questions are only a guideline for what could be asked during the course of the interview. With this method the interviewees have the freedom to speak about their concept of the gate occupancy at Schiphol or any other relevant subject useful for this research. During the interview the responses are written in keywords and typed in full detail afterwards, the typed interview is shared with the interviewee in order to prevent misinterpretations.

2.4 Sample

During summer season there are much more flight movements at Schiphol, therefore the gate schedule is even tighter during this period. According to IATA the aviation summer season ranges from 26th of March 2017 until the 29th of October 2017 (IATA, 2017). The year of 2017 is used as it is most relating to the current situation at Schiphol airport. Before this complete summer season

⁴ Please refer to appendix VII for a list of Schengen countries.

2017 data will be included in the analysis, a sample of one month of the data will be analysed to understand the data. Afterwards the research techniques will be applied to the complete dataset.

Interviews will be held with 5-10 interviewees that are working for key stakeholders at Schiphol airport, focusing on airlines and ground handlers as it is expected that these parties have most information on the gate occupancy.

2.5 Data Collection

Only data from KDC Mainport stakeholders is needed and therefore should be easier to collect and analyse compared to data from stakeholders outside the cooperation.

Every day millions of records are produced on and around Schiphol. The LVNL produces A-CDM data, Schiphol produces information about passengers in the terminal and KLM knows constantly what the technical state is of their aircraft. In all that data it is expected that some errors are made. The data is filtered to avoid to consider some mistakes contained in the dataset. Because the complete summer season of 2017 will be researched, there should be enough data to cover the imperfections.

During data analysing and when conducting interviews the ethical considerations, seen in appendix VI, will always be followed. All results from analysis will be presented anonymously. Consent is searched with interviewees to display name, job title and company.

2.6 Data Analysis

The programs of Researchgate and Mendely are used for the literature review (Researchgate, 2018) (Mendeley, 2018).

Nowadays many tools are available for analysing data and displaying the results in such a way that the research is clear. Excel is used for analysing the A-CDM data of the LVNL and the SIBT data of Schiphol. All data is put together, filtered and aggregated which results in reliable data that contains the answers to all research questions. When the data analysing with Microsoft Excel is completed, other tools were used for displaying the data. Spotfire is a data visualization tool used by, among others, KLM for displaying all kinds of data in a clear way. One of the major benefits is that data can easily be filtered or changed compared to Excel, saving time and having better results (TIBCO, 2018). All research results are put in the Spotfire program, resulting in understandable graphs and figures.

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3 Review of the Literature

This literature review will elaborate on what has already been investigated and researched about airline strategies' impact on capacity. Paragraph one introduces literature research on the difference between airline business models, paragraph two will relate the differences between hub and non-hub airports. The literature on incentives and drivers for airlines is discussed in paragraph three and the final paragraph contains some concluding remarks.

3.1 Airline business models

Currently a total of 279 airlines are member of the International Air Transport Agency (IATA), ranging from airlines with only one aircraft to airlines with over a 1,000 aircraft in their inventory (IATA, 2018). All these airlines can be categorised into several airline business models, depending on how the airline operates. These business models are described in the book 'Air Transport Management' (Budd & Ison, 2017).

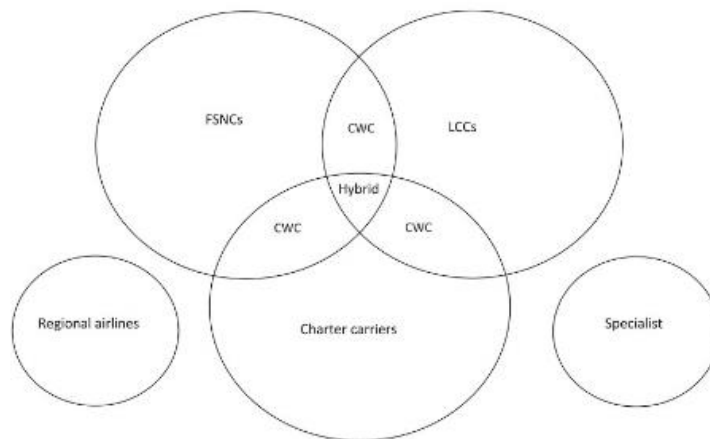


Figure 5, Airline business models (Budd & Ison, 2017).

The German Aerospace Centre (DLR) issued a topical report on airline business models in December 2008 (Reichmuth, et al., 2008). This report describes the characteristics of the airline business models as follows (Reichmuth, et al., 2008):

Full Service Network Carriers (FSNCs) are airlines providing both regional and long-range flights from their hubs, the flights include on-board service and various classes. The regional aircraft mostly work as feeder flights to the hub where the long-range flights depart, meaning a hub-and-spoke network is operated. Nowadays most FSNCs are mostly privatized. Characteristic of FSNCs is the fleet, which compromises both regional feeder aircraft and long-range wide body aircraft. The carriers' network range is mostly both domestic, international and intercontinental. The aircraft have at least 3 service classes and therefore the yield management is complex.

Low Cost Carriers (LCCs) focus on operating their flights as efficient as possible, maintaining as low as possible costs per flight. These airlines make use of young aircraft that are of the same type which leads to lower costs in fuel, maintenance and staff. The aircraft are equipped with an as high as possible amount of seats resulting in lower unit costs and more capacity. Generally ground times are reduced by using secondary airports and flying point-to-point (P2P), this strategy maximizes the amount of possible flight hours per day. The in-flight services of LCCs are not complimentary, snacks and drinks have to be paid for. Contrary to the FSNCs, the passengers have to pay for their hold luggage. Selling these products creates ancillary revenues, this revenue stream is becoming more and more important for the airlines (O'Connell & Williams, 2016).

Formerly characterized as charter carriers, holiday carriers mainly focus on the transportation of tourists. Nowadays the services operate as scheduled flights, however, the flights are still mostly seasonal. Like the LCCs, holiday carriers operate their flights P2P with young aircraft of mainly the same type. Unlike the LCCs they offer in-flight services like meals, drinks and video screens for free. The biggest difference between LCCs and holiday carriers is the yield management,

holiday carriers usually charge average cost prices that fluctuate according to the seasonal demand. Also the frequencies differ between the carriers as people tend to go on holiday for one or two weeks. Furthermore holiday carriers operate both medium- and long-haul aircraft, depending on which holiday destinations are served, examples of holiday carriers at Schiphol are TUI NL and Corendon.

Regional carriers typically operate aircraft with 20-100 seats and focus on a particular area or region. (Reichmuth, et al., 2008). Some carriers operate on their own, other regional carriers operate for FSNCs to connect the airlines' hub with regional airports. When operating independently the regional carriers share commonalities with LCCs as they aim to have low turnaround times and point-to-point passengers.

Apart from above mentioned passenger airlines, some airlines focus on air freight. These airlines have three ways of operating: Combination airlines that only carry belly cargo for extra revenue, FSNCs that operate full freighter aircraft apart from their mainline operation and all-cargo airlines that only operate a full freighter fleet. The cargo flows are different from the passenger flows, determined by the international trade flows the cargo flights are operated. A differentiation within the all-cargo airlines is made between traditional operators and integrators. Integrators provide a door-to-door service for mail and smaller cargo while the traditional operator transport all kinds of goods but only operates the flight.

Hybrid carriers operate with the characteristics of both FSNCs, LCCs and charter carriers. Examples of hybrid carriers are Aer Lingus and Norwegian (Klophaus, Conrady, & Fichert, 2012). Aer Lingus operates low cost short haul services from Dublin and at the same time uses these low cost flights to feed their full service transatlantic services. Norwegian nowadays operates both short haul and long haul low flights, from various hubs in and outside Europe they provide these services. Airlines that operate between two business models are named Carriers Within Carriers (CWC) such as KLM Cityhopper that operates both as a regional airline as well as a FSNC (Budd & Ison, 2017). Apart from above mentioned airline business models there are specialist airlines that specialize their service for a specific target group, mostly flown as part of a public organization.

All in all, there are a lot of different airline business models that each have their own ways of operating. Using the defined characteristics described by Lucy Budd & Stephen Ison and the DLR there are six types of airline business models: FSNCs, LCCs, holiday carriers, regional carriers, freighter airlines and hybrid carriers.

3.2 Hub and non-hub airports

Around the world there are 41,820 airports that are recognizable from the air, however most of these airports do not have enough facilities for handling a commercial jet-aircraft (CIA, 2016). Only a limited amount of airports have the ability to facilitate transfer passengers, travelling from origin to destination via an airport in-between. Airports can be categorized on multiple ways, ranging from which aircraft are able to land to the amount of passengers and transfer passengers (FAA, 2018). This paragraph only discusses the primary and secondary airports. The differences between primary and secondary airports can sometimes be very small. Typically primary airports are major hubs with multiple runways and many transfer passengers while secondary airports usually have a limited amount of runways, less facilities and only P2P flights. Examples primary airports are Schiphol airport, Paris Charles-des-Gaulle and London Heathrow. Secondary airports include for example Eindhoven airport, Paris Beauvais and London Stansted.

Generally secondary airports have lower flight movements, less annual passengers and less facilities for those passengers. These differences result in the overall airside capacity difference, this is described by Bojana Mirkovic and Vojin Tosic who analysed the differences between hub and non-hub airports with an airside capacity perspective (Mirkovic & Tosic, 2017). In their opinion the apron capacity is derived from the number of aircraft stands and average stand occupancy times (SOT), taking into account traffic mix and differences between operators. The SOT consists of at least the turnaround time (TAT) of all operators and time in-between the turnarounds for separation (ST). Only at non-hub airports the general calculation for apron capacity can be used, at hub airports the dominant airline coordinates their flights in waves which creates peaks in apron demand. The wave structure at an airport is determined by the minimum connecting time (MinCT), the maximum connecting time (MaxCT) and the maximum number of flights per wave as can be derived from figure 3. The wave repeat cycle is the time interval

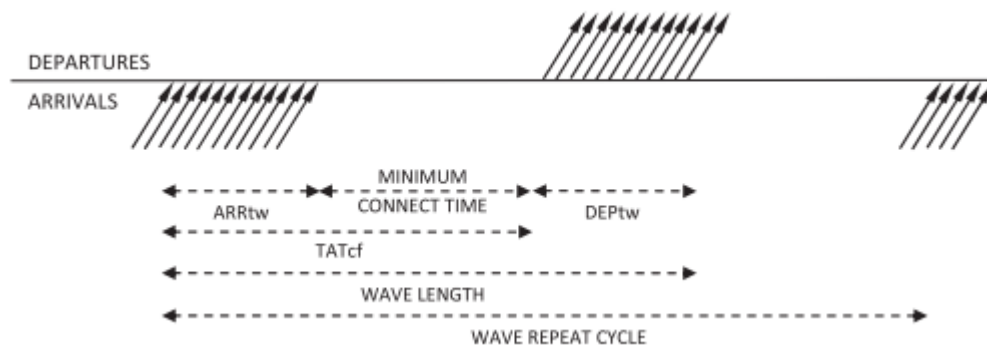


Figure 6, Split wave pattern (Mirkovic & Tosic, 2017).

between the consecutive waves. The minimum connecting time at Schiphol is 40 minutes for transfers between European flights and 50 minutes when the inbound or/and outbound flight is intercontinental. The maximum connecting time is not determined by the airport but by the airline, the connecting time reflects a level of service and should be convenient for the passenger. Generally, the MaxCT of KLM is 300 minutes, other options are also available if the passenger wants to spend some time in Amsterdam.

With above mentioned factors for apron capacity the following formulas have been created:

$$Ct = N/SOTcf$$

This formula calculates the theoretical apron capacity (Ct) by dividing the maximum number of aircraft per wave (N) by the stand occupancy time for all coordinated flights (SOTcf).

$$Cu = N/WRC$$

Above formula calculates the actual apron capacity (Cu) by dividing N by the wave repeat cycle (WRC) which reflects the stand occupancy time as can be seen in figure 6.

Most hub airports do not operate as a pure hub airport, they operate a mix of both transfer and P2P flights which creates a difference in calculating the apron capacity. The apron capacity is then defined as the minimum of the capacities set by the group of stands for coordinated flights and the group of stands for other flights, these are accounted for during the WRC period. The factors that can have effects on apron capacity for different types of airports can be derived from table 3 on next page.

Table 3, Factors affecting apron capacity for different types of airports (Mirkovic & Tomic, 2017).

	O/D airport	Static apron capacity (N-stat)	Max no. of aircraft in a wave due to MaxCT (N-MaxCT)	Pure Hub (only coordinated flights)		Mixed hub (coordinated + P2P flights)	
				Theoretical	Utilized	Preferential	Exclusive
Number of stands	X	X		X	X	X	X
Demand structure	X	X		X	X	X	X
Turnaround time	X					X	X
Separation time	X			X		X	X
Maximum acceptable connecting time			X	X	X	X	X
Minimum connecting time			X	X	X	X	X
Wave repeat cycle				X	X	X	X
Runway capacity			X	X	X	X	X

The conclusion of the research is that the functional relationship between the runway system and apron/gate area is much stronger in the case of hub airports and should therefore be considered to identify bottlenecks on airside terrain of an airport (Mirkovic & Tomic, 2017). Furthermore the apron capacity at hub airports is dependent on above mentioned factors which are important when improvements are considered for services or changes in resource allocation strategy.

Schiphol airport

Over the past years Schiphol airport has grown tremendously, in ten years the airport has grown from little over 50 million passengers to 68.5 million passengers (Schiphol Group, 2018). In 2017 the airport had almost 497 thousand aircraft movements which were accommodated across six runways. To manage the growth several researches have been and will be conducted to see how the airside capacity can be optimized (Westerveld, 2017).

One of these researches has been initiated by the KDC and was conducted by the Netherlands Aerospace Centre (NLR) and the consultancy company of Moving Dot (Jester, van Ravenswaaij, The, van Dronkelaar, & de Muynck, 2017). The objective for this research was to develop priority rules to help optimize the airport throughput, specifically in the area of gate availability and management. With the help of statistical data, simulations and an established set of priority rules the research was carried out. Through interviews the bottlenecks experienced by the stakeholders and the proposed recommendations were identified, part of these bottlenecks and related recommendations can be seen in table 4 below (Jester, van Ravenswaaij, The, van Dronkelaar, & de Muynck, 2017).

Table 4, experienced bottlenecks and stakeholder recommendation.

Stakeholder	Experienced bottlenecks	Stakeholder recommendations
Legacy carrier	Insufficient gate capacity requires use of (undesired) buffer handling.	Improve TSAT calculations (less fluctuations). Improve quality of buffer handling (passenger boarding steps with canopies, improved waiting rooms).
Low cost carrier	Aircraft access to H-pier is an issue. Availability of gates is insufficient. Turnarounds at other than gates at H-pier take longer than 30 minutes.	Operations not to be hampered by wide-body push-back. Buffer handling: covered aircraft stairs

Stakeholder	Experienced bottlenecks	Stakeholder recommendations
AAS	Increasingly limited availability of gates and buffer positions.	Slots should be allocated based on gate availability. All stakeholders to provide up to date and reliable information, claim free culture should be created.
LVNL	ATC is dependent on available aircraft stand (VOP) allocation of a flight to ensure a smooth and efficient taxi process. Only +/-15 minutes prior to landing a flight becomes visible on the Electronic Data Display (EDD) of the ground controller, leaving little time for planning.	Information on gate availability is not directly available to ATC. This information may be useful when an aircraft was due to be ready but is still occupying the gate. Currently, gate management needs to be consulted on how long a situation will last.
Ground handling providers	Gate planning at H-pier is controlled by AAS, operations might be more efficient if the ground handler would be responsible or more directly involved in local gate planning and allocation.	Coordinate last minute gate changes between AAS and ground handler. TSATS should be more reliable More aircraft parking positions (gate, buffers) are needed.

3.3 Turnaround differences

As discussed in paragraph 3.2.1 there are different airline business models that all have different characteristics. One of these characters is the turnaround differences between airlines as some may turn their aircraft around in under 30 minutes while others take an hour or more (Francis, Dennis, Ison, & Humphreys, 2007). All variation in turnaround techniques in this paragraph are categorized according to airline business model.

An aircraft lands at the airport, taxis to the aircraft stand and starts the turnaround when the wheel chocks are applied. Ground handling will then start all turnaround services such as (de)boarding, (un)loading of baggage and cargo, refuelling, cleaning, etc. When the turnaround is finished, the aircraft is pushed back to the taxiway and starts taxiing before it takes off towards its destination. The amount of time this process takes differs per airline, on average LCCs have much lower turnaround times compared to FSNCs. A reason for this is excluding the gate bridge to let the passengers enter the aircraft using stairs at the front- and aft door (Dennis, 2007). Another advantage for the LCCs during turnaround times is that their passengers have less bags that have to be put into the luggage hold because hold luggage has to be paid for, this means less time is spent during unloading and loading luggage.

Generally non-hub airports have a more simplistic airside configuration compared to hub airports (Mirkovic & Tasic, 2017). This simplistic airside configuration may lead to lower turnaround times, therefore most LCCs prefer non-hub airports to operate from (Budd & Ison, 2017) (Mirkovic & Tasic, 2017). Hub airports on the other side have a wider range of services, more ground handling providers and the ability to service wide-body aircraft. A trend that can be seen at hub airports is the creation of low-cost terminals, which is also the case at Schiphol airport with the H-pier where airlines like Ryanair, EasyJet and WOW air are serviced. The terminals are dedicated to LCCs and are designed to be more efficient (Budd & Ison, 2017). Another aspect of hub airports is the Minimum Connecting Time (MCT), which is a benchmark the airport sets for the minimal time needed for a passenger transfer including bags. At Schiphol the MCT is 40 minutes between connecting European flights and 50 minutes when either the inbound and/or outbound flight is intercontinental.

FSNCs have other strategies for turnarounds of their aircraft like owning the ground handling company, prioritizing transfer passengers and the use of wide-body aircraft. An advantage of owning the ground handling service provider is that all services are carried out exactly the way the airline has designed. The priority for FSNCs are the transfer passengers, these passengers have to transfer at the hub of the airline and catch their connecting flight in order to get to their final destination. Sometimes an aircraft is put on hold at the gate because a (group of) passenger(s) had a delay on the incoming flight. On the contrary holiday carriers do not have

transfer passengers at all, not even for their wide-body aircraft which should make their turnaround times more efficient. To increase the daily aircraft use, like LCCs, the turnaround times of holiday carriers are as short as possible. The difference between LCCs and holiday carriers is the amount of hold baggage, passengers who are going on a holiday tend to bring hold baggage instead of only hand baggage which means more time is needed for loading and unloading of all bags (Budd & Ison, 2017).

Use of smaller aircraft means that less equipment is needed for the turnaround of a regional carrier aircraft. The baggage hold mostly is reachable from the ground meaning no baggage belts are needed and the amount of passengers per aircraft is lower meaning that boarding will take less time.

The turnaround of freighter aircraft is very different from passenger airlines, they are serviced at a cargo platform using different equipment to unload and load all freight. Because of the fact that freighter airlines do not make use of gates, this group is excluded from the research

Hybrid carriers can be a mix of all kinds of airline business models. An example is Norwegian airlines that will start operating long-haul routes from Schiphol on 7th of May 2018 by flying four times a week between Amsterdam and New York John F. Kennedy airport with wide-body aircraft while also operating European flights with narrow-bodies (Norwegian, 2017). As Norwegian closed a deal with EasyJet for passengers to transfer at Schiphol, transfer passengers have to be taken into account.

All in all, it seems that there are differences between airline business models when looking at the turnaround processes. FSNCs prioritize their transfer passengers and want to offer the best possible service, this is accomplished by servicing the aircraft with their own ground handling service provider. LCCs focus on speed and efficiency and make use of dedicated low cost terminals if available at hub airports, otherwise they mostly prefer to operate from non-hub or secondary airports to minimize the time spent on the ground by the aircraft. Holiday carriers operate a mix of both wide- and narrow-body aircraft and have more baggage as their passengers are going on a holiday, no aircraft have to wait for transfer passengers as the traffic is P2P. By using smaller aircraft, regional carriers need less equipment for their turnaround process. Freighter aircraft do not make use of gates while hybrid carriers are a mix of business models that have various ways of operating.

3.4 Delay recovery techniques

All aviation related delays have major consequences to all stakeholders involved, one of these consequences are the costs involved. Airline delays are hard to manage as most delays occur unexpectedly, with disruption management the airline tries to minimise the costs resulting from operational disruptions (Budd & Ison, 2017). There are a lot of different traffic flows that come from an ordinary flight, shown in figure 7 is an example of what the traffic flows are of a flight from Rome to London. Aircraft, passengers, cabin crew and flight crew all go their own way after a flight so when the flight is delayed, there are consequences for all following directions.

In February 2004 the European Union (EU) established common rules on compensation and assistance to passengers in the event of delays with regulation 261/2004, these rules became operational one year later (European Union, 2004). The regulation contains a total of nine rights that are obligatory for all airlines that operate in the EU member states. One of these rights is the right to compensation, passengers have the right to get compensations between €250 and €600 for a delay between 2 and 4 hours depending on the flight distance. Another right is to receive care: passengers should be offered meals and refreshments during the delay. When the stay of one or more nights becomes necessary the airline should offer free of charge hotel accommodation and transport to and from the accommodation. The documented rights have a big influence on the disruption managements of airlines as there are high costs involved for the airlines.

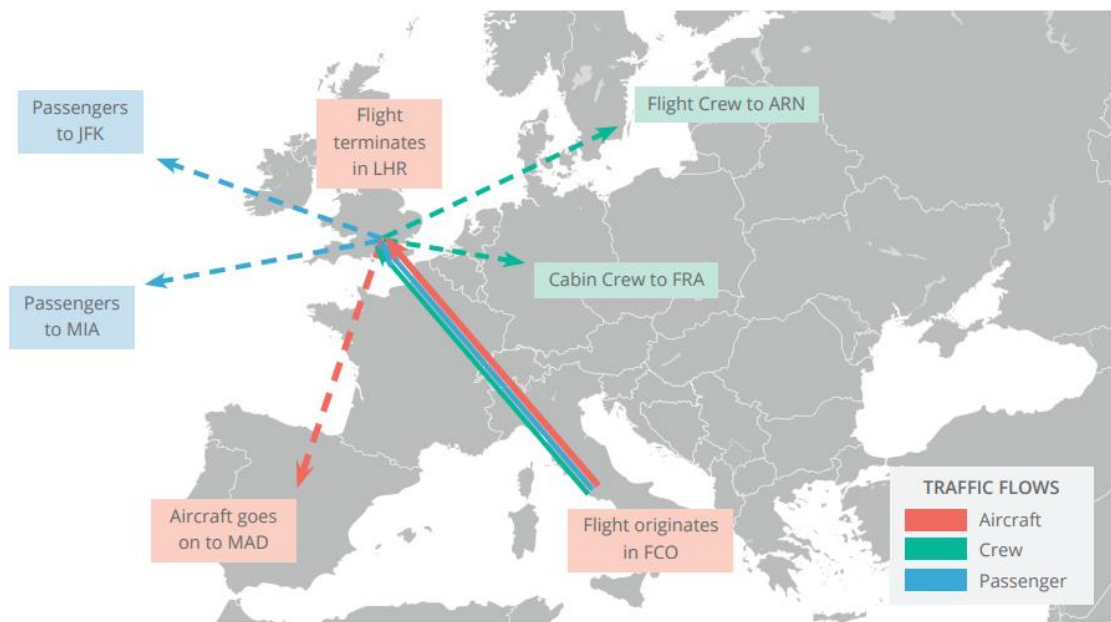


Figure 7, Traffic flow example (Gershkoff, 2016).

Apart from the fact that passengers have their aircraft travel rights, the reputation of the airline is at stake during a delay. Research has proved that flight delays on a route impact both passenger demand and average fare, demand goes down while the fare will increase (Britto, Dresner, & Voltes, 2011). The demand is affected because passengers do not seem to forget or forgive airline mistakes that result in the delay of their flight, this means the airline reputation is impacted (Ferrer, Rocha e Oliveira, & Parasuraman, 2011).

Because of all above mentioned impacts the airlines use both proactive and reactive disruption management to minimize all consequences of a delay. Proactive measures include increasing turnaround times to have higher buffers against delays, having aircraft swapping opportunities and using a robust planning (Budd & Ison, 2017). The use of proactive measures reduces the potential impact of schedule disruptions and therefore the impact on passengers. When an event causes schedule disruption, the airline has to use reactive disruption management measures. These measures include delaying or cancelling aircraft, rescheduling of aircraft and/or crew, using reserve crews or transporting the crew as passengers to operate a flight from an outstation.

In summary the airlines want to prevent delays as much as possible because the consequences are high, they do this by using pro- and reactive disruption management measures. Consequences for the airlines are documented in EU regulation 261/2004 where all rights for airline passengers are stated, apart from this consequence it has also been proven that delays impact passenger demand and average fare. To make sure there are as low as possible delays, airlines use measures like scheduling higher turnaround times, even if the delay has already occurred the airline still has options like using reserve crews for operating the flight.

3.5 Conclusion

There are six defined airline business models who all have their own characteristics, for example the operation at a hub or non-hub airport. The difference between these two is the simplicity of the airside infrastructure, as non-hub airports tend to be smaller there is less congestion. A result is that turnaround times at non-hub airports usually are less, also there is much variation in turnaround times between the airline business models. To make sure that all flights are operated as scheduled most airlines make use of proactive disruption management, when operations are disturbed however active disruption management is started to minimize the impacts.

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4 Research analysis

This chapter contains the additional research steps that have been taken after the research methodology towards the research findings. The analysis has been conducted per sub research question, which are as follows:

1. What are the strategy differences between airlines operating at AAS?
2. What is the impact of airline structures and airline traffic mix on gate occupancy of AAS?
3. What delay recovery techniques are used by airlines at AAS and what is their impact on the airside capacity of AAS?

Above questions have been the subject of all data research. Quantitative data is used to research the difference in scheduled and actual turnaround time of every flight, these flights are categorized in airline business models as to find out what the impact is of the business models on the gate occupancy at Schiphol airport. This data is collected with use of datasets of both LVNL and AAS, which are combined and resulted in one dataset with all research findings. Apart from these datasets, interviews are conducted with key stakeholders who have a different view on the gate capacity at Schiphol. The results from these interviews are already displayed in the final paragraph of this chapter.

4.1 Defining strategy differences between airlines at AAS

For answering the first sub question only literature sources are used, data however is used for showing the differences at Schiphol airport. All differences between airline business models can be found in chapter 3. Some airlines belong to multiple airline business model categories, the site of CAPA is then used for checking which business model matches best to the airline characteristics (CAPA, 2017). With the information found in the literature a list of airlines is created with several categorization aspects as can be derived from table 5 & 6 below, the complete list with all airlines and their business models can be found in appendix X.

Table 5, key airline BM categorization aspects.

Airline BM categorization	Remarks
Business model 1	Key business model according literature review and CAPA.
Business model 2	Additional business model.
Flight range	Categorized in short-/medium- and long-haul
Aircraft fleet mix	Categorized in WIBO/NABO

Table 6, additional airline BM categorization aspects.

Airline BM categorization	Remarks
Name of airline	
Callsign	Three-digit start of callsign code.
Base/Non-base carrier	Whether the airline has aircraft based at Schiphol airport.
Ground handler	Which ground handler manages the airlines' turnaround.
Security type	Whether the airlines' destination are Schengen/Non-Schengen or both

When an airline operates using multiple business model characteristics while not being a hybrid carrier a second business model is added. For example FSNC that operate full freighters or KLM Cityhopper that operates both FSNC and regional. Seven base passenger carriers are identified at Schiphol, the distinction is made because ground times can differ between base and non-base carriers as the base carrier aircraft stay overnight and could have a longer turnaround time if a longer buffer is scheduled between flights. The ground handler customers are identified using Schiphol data and are displayed as they could give insight into whether ground handlers have

impact on the gate occupancy. The flight range categorization is made using table 7 below, appendix IV contains a visualization of what the distance is from Schiphol airport (Great Circle Mapper, 2018).

Table 7, flight length distribution.

Legend range	Hours	Distance
Short-haul	0-1,5 hours	0-500 NM
Medium-haul	1,6-5 hours	501-2500 NM
Long-haul	>5,1 hours	>2501 NM

The aircraft mix is categorized according which aircraft type operated the movement, defined in wide-body or narrow-body, depending on fuselage width. The destination or arrival airport are divided into Schengen and Non-Schengen depending on what the security classification is of the country, see appendix VI for a visualization of all Schengen countries.

As discussed in the literature review, the airline business models all have their own characteristics. One of those is the ground time or turnaround time at an airport, usually a LCC has a lower turnaround time compared to a FSNC to have more flight hours per day. The turnaround time of every airline is translated to a Minimum Ground Time (MGT), this is the minimum time an airline needs to operate a complete turnaround process. LCCs for example have MGTs of around 30 minutes while most FSNCs schedule at least 45 minutes.

The quantitative data contains, among other data, the actual and scheduled turnaround time and the aircraft type used per flight. This data is visualized and explained further in chapter 5.

4.2 Airline strategy impact on gate occupancy

To research the impact of all airline business models on the gate occupancy multiple categorizations are made. These categorizations include among others airline business model, flight duration and base or non-base carriers. Using these parameters the exact impact of the airlines on the gate occupancy of Schiphol airport is researched.

The declared runway capacity for Schiphol 2017 summer season, seen in table 8 below, has been created by the LVNL and published by Airport Coordination the Netherlands (ACNL, 2016). This organization is the airport slot coordinator for Schiphol, Rotterdam The Hague and Eindhoven airport.

Table 8, Schiphol runway capacity summer season 2017 (ACNL, 2016).

ATM mode	Possible within period from – to (UTC)	Nominal hourly capacity		Nominal capacity per 20 minutes	
		IFR arrivals	IFR departures	IFR arrivals	IFR departures
Day; departure peak mode (S)	05:00 – 19:39	36	74	12	25
Day; arrival peak mode (L)	05:00 – 19:39	68	38	23	13
Day; off peak mode (O)	04:00 – 04:39	24	30	8	10
	04:40 – 04:59	24	40	8	14
	05:00 – 20:39	36	40	12	14
	20:40 – 20:59	36	25	12	9
Night mode (N)	21:00 – 03:59	24	25	8	9

This capacity declaration purposes both commercial and general aviation. During summer season 2017 the planning limit was exactly the same as the movement capacity being 313,740 movements of departures and arrivals for commercial aviation.

London Heathrow, Frankfurt airport and Paris Charles des Gaulle have similar maximum hourly capacities. During summer 2017 the maximum predicted hourly capacities at Heathrow,

Frankfurt, Paris and Schiphol were 90, 100, 120 and 110 movements respectively (ACL, 2016) (FLUKO, 2017) (Paris Aéroport, 2016).

All these maximum flight movements are based on the runway capacity at the airport, the maximum gate capacity does not influence the amount of theoretical runway capacity. However when an airport has congestion at the gates, aircraft could turn up waiting on taxiways or buffers for an available gate. To minimise this congestion a robust gate planning is created and no problems should arise when this planning is followed, in aviation however almost nothing goes exactly like scheduled.

In total Schiphol airport has 149 aircraft stands divided over the A, B, C, D, E, F, G, H and J platforms as seen in appendix XI. All aircraft stands are categorized according the length and wingspan of the aircraft according table 9 below. The stand categories at Schiphol airport range between 3 and 9.

Table 9, Schiphol gate categorization (Schiphol, 2018).

Category	Maximum length (m)	Maximum wingspan (m)
1	22	24
2	28	29
3	37	29
4	45	36
5	49	44
6	55,5	52
7	72	61
8	76	65
9	77	80
10	84	88,4

Based on the datasets of LVNL and Schiphol, seen in table 1 & 2, a combined dataset is created. This dataset includes the SOBT of the Schiphol dataset, as the LVNL dataset did not include this value. Afterwards the calculations are made which created the final dataset as can be seen in table 10 and more detailed in appendix V. This final database is used to research the gate occupancy times of all different airline business models:

Table 10, combined dataset.

Name in data	Stands for:	Remark
Datum	Date	
A/D	Arrival/departure	Shows whether the movement was an arrival departure.
AOBT	Actual Off-Blok Time	AOBT of the departing flight, displayed behind the arriving flight.
SOBT	Scheduled Off-Block Time	SOBT of the departing flight, displayed behind the arriving flight.
ATAT	Actual Turn Around Time	Time between AIBT and AOBT.
STAT	Scheduled Turn Around Time	Time between SIBT and SOBT.
Airline BM	Airline Business Model	Shows to which business model the flight belonged, according predefined categorization.
Flight duration	Flight duration	What the duration was of the flight according predefined durations.
Base carrier	Type of airline	Whether the airline is an airline with aircraft based at Schiphol according predefined list.
NABO/WIBO	Narrow body/Wide body	Whether the used aircraft type fuselage is narrow or wide.
Diff A-S	Difference between Actual and Scheduled turnaround time	What the difference is between the actual and scheduled turnaround time, in minutes.
Ground handler	Ground handler	Ground handler that handles the airline.
Recat-EU	Wake turbulence category	According RECAT-EU, see appendix IX
Pier	Pier of handling at Schiphol	

While approaching the runway, aircraft should have enough separation because of wake turbulence. Where an aircraft flies through the air, the air behind the aircraft becomes unstable and other (smaller) aircraft could run into problems. The wake turbulence categorisation and separation minima are determined by ICAO and Eurocontrol, currently having six different categories ranging from Super Heavy to Light as can be seen in appendix IX and simplified in table 11 below (Eurocontrol, 2015). Depending on aircraft category the separation ranges between 8 and 2,5 Nautical Miles (NM).

Table 11, RECAT-EU wake turbulence categories according Eurocontrol (Eurocontrol, 2015).

RECAT-EU Category	Classification	Examples
Super heavy	J	AN-124, A380
Upper heavy	B	A332, B744
Lower heavy	C	MD11, B763
Upper medium	D	B738, A320
Lower medium	E	E190, AT45
Light	F	SF34, LJ35

This RECAT-EU wake turbulence category is used as it shares more similarities with the gate categories at Schiphol. These separation minima are not yet used in the air by the LVNL. A KDC research however, researched the benefits of adopting these updated separation minima.

The categorization between base- or non-base carrier is made as base carriers tend to have a higher gate occupancy because more time is scheduled between flights. Non-base carriers use Schiphol airport as an outstation and therefore usually have lower gate occupancy. The following passenger airlines have been identified as Schiphol base carriers:

- Corendon Dutch airlines
- Delta Airlines
- easyJet
- KLM
- KLM Cityhopper
- Transavia
- TUI airlines Netherlands

Apart from the predefined categories it turned out that some other variables could also be of use for the results, these were:

- Arrival/departure
- Pier of turnaround at Schiphol

Based on what is mentioned in the departure airport and arrival airport it turned out easier to filter these values by adding a column with arrival/departure movement. As proven to be easier while working with the dataset, the pier of turnaround at Schiphol could be filtered and used for displaying results. This is done because it will give insight into the difference in gate occupancy per terminal pier at Schiphol airport.

4.3 Gate capacity experiences

Experts and stakeholders applicable to this research were asked to participate in an interview and answer questions about the influence of airline business models on the gate occupancy at Schiphol airport. The following experts and stakeholders participated:

- S. Pots, Supervisor Operations NL at Aviapartner
- Anonymous 1, KLM Ground Services
- Anonymous 2, KLM improvement team B737
- P. Wiegant, Duty Hub Manager at KLM
- S. Prent, Service Owner Aircraft at Schiphol
- R. van Breda, Areamanager Schiphol at Transavia

Other important stakeholders have been contacted but did not provide a response. As identified earlier the interviews are conducted unstructured, meaning there is no planned sequence of questions to be asked to the interviewee. Below interview questions are asked to steer the interviewee in the right direction, answers therefore may deviate from the displayed question.

4.3.1 How do you experience the gate capacity problem at Schiphol? What are the impacts on your operation?

More and more use of buffer platforms is made for handling aircraft during their turnaround, these platforms are further from Schiphol centre and therefore causes problems when transporting resources (Pots). Also Pots, anonymous 2 and Wiegant emphasize that the passenger and flight movements increase did not result in additional gate capacity, therefore the schedules became tighter, as described in (Peters, 2018). Especially during particular timeframes such as Monday or Saturday morning the gate planning is very tight, giving the feeling that there is not enough concrete for all aircraft to be handled (Pots, Wiegant). The Regulation Aircraft Stand Allocation Schiphol (RASAS) contains the guidelines for Schiphol to assign gates to all aircraft. One of these guidelines is that the aircraft stand is scheduled from 10 minutes before or after the Scheduled In-Block Time (SIBT) until 10 minutes before or after the Scheduled Off-Block Time (SOBT), in practice part of the involved stakeholders think that the SIBT and SOBT are not realistic because an aircraft almost never arrives or departs exactly according schedule as can be derived from Wouters (Wiegant, Prent) (Wouters, 2018). During planning it also seems that the airline Minimum Ground Time (MGT) is not monitored as the term was not recognized. Some aspects of the MGTs are used at for example the H-pier where 95% of all turnarounds should be below 30 minutes and the rest below 40 minutes, no penalties are given however as it is not monitored whether the guidelines are exceeded (Prent).

Furthermore Prent explains that 6-10 wide-body and 6 narrow-body aircraft stands had to be in place to cope with the extra traffic of summer season 2018. This has been solved by temporarily changing the J-platform from a buffer to additional aircraft stands, including turnaround equipment. A benefit for airlines is that buffer handling gives 20% discount on the landing/take-off charges, therefore some airlines do not see of it as a problem at all. Downsides are that ground handling cannot bring their own equipment and that some airlines think of it as passenger abuse because of bus transport and risk of adverse weather conditions (Wiegant, Prent).

In general the involved interviewees see the role of the KLM flight coordinator (Dutch: vlucu), situated next to the gate planner of Schiphol as a major benefit (anonymous 2, Wiegant, Prent). This KLM employee connects easy to all KLM departments such as ground services, the operations centres or Cityhopper and helps the gate planner to optimize the gate planning. Anonymous 2 mentions that KLM set up a complete team to think of possible improvements for both their 737 and intercontinental fleet, an improvement thought of by this team is to board and de-board the aircraft using stairs at both the front- and aft-side of the aircraft.

As mentioned in Wouters (2018) the implementation of local A-CDM did not provide a better on time performance (OTP) compared to before the implementation. Especially during adverse weather conditions the Target Start-up Approval Time (TSAT) varies constantly, resulting in a far from robust schedule. Pots, anonymous 2, Wiegant and Prent emphasize this statement, telling in their own words that the TSAT varies constantly for example when a third runway is put in use or not. The Target Off-Block Time (TOBT) is determined by the ground handler and is mainly changed within the last 10-15 minutes as only then an accurate estimate of the TOBT can be determined (Pots). At the moment KLM is running tests with an app called 'PLUG', this app shows all separate handling processes where the supervisor of the specific process can fill in when the process was started resulting in an earlier and better TOBT estimation (anonymous 1). This app is also useful for monitoring the MAC value of an aircraft. This value represents the aircraft centre of gravity in relation to the cord of the aircraft centre wing (Flight Mechanic, sd). When the centre of gravity is not between the front or main gear, the aircraft tips on its tail and damages itself. Therefore an aircraft has a defined MAC value range which should not be exceeded. This is also the difference between KLM and Transavia as van Breda explains that the MAC value is not monitored by Transavia's handler.

Prent is also able to describe some type of airlines, stating that holiday carriers want to operate as low cost as possible and operate less flights per day as holiday destinations are further from

Schiphol. Furthermore Prent states that FSNC often wait for their connecting passengers at the gate. Also KLM Cityhopper is considered more as a regional carrier because this airline works with Quick Turnarounds (QTA) and has its own procedures at the A-platform (Wiegant, Prent).

4.3.2 Are aircraft of your airline/customer delayed at the gate for other than ATC/airport related delays? For which reasons?

Pots, Wiegant and van Breda provided their view about for which reasons their airline or customer could be delayed at the gate for other than ATC or airport related delays. Airlines with a base at Schiphol have multiple aspects to be taken into account, a late aircraft crew could for example result in a delayed departure. Both anonymous 2 and van Breda however state that their airlines generally do not wait for transfer passengers beyond the scheduled departure. When a passenger is marked having a risky connecting time at Schiphol airport their bag is transported directly from their arriving to their departing flight and loaded last on this flight, therefore when the passenger does not make the connection the bag is unloaded fast. Bags in the aircraft belly that do not belong to any passenger on board is marked as a delay reason by Pots and anonymous 2 as it means that the cargo doors have to be opened again to remove the baggage. A rule for airlines operating to and from the United States of America (USA) is that baggage should not be in the hold for over 20 minutes without the carrying passenger in the aircraft.

A reason for delay marked by all three participants are delays caused by technical difficulties with the equipment. Unfortunately this is bound to happen with every airline or customer once in a while, the consequences could be high especially when the technical difficulty results in a cancellation. Furthermore it seems that also cockpit crew sometimes delays flights by for example asking for extra fuel because of en route weather changes (van Breda). Also van Breda states that its airline does not monitor the MAC value of their aircraft during ground handling, therefore turnarounds are conducted according an aircraft with a high risk of tail-tipping. Pots remarks that a few European carriers tend to wait more often for their passengers to show up at the gate, never for more than 30 minutes however as the consequences otherwise become problematic.

Anonymous 2 explained that during the peak of the peak (roughly 15 minutes between 8AM and 11AM), 10-15 extra personnel could be used for servicing turnarounds. These extra personnel are not hired however because personnel have to be hired for at least 3 hours, with this personnel only needed for a short time period the productivity would be not enough.

It was expected that FSNC would wait more often for their transfer passengers to show up, it seems however that these carriers do not wait for the passenger and rebook their itinerary for the next available flight.

4.3.3 Which delay management measures/procedures does your airline/company use?

Because passenger delays are very costly to almost all aviation stakeholders, a lot of effort is put into avoiding delays and if it occurs manage the delay to minimize the impacts. Anonymous 1 mentions the implementation of the PLUG app which should result into better awareness of each ground handling process. Another recent development is to board and de-board the aircraft through both front and aft-door, a new development for KLM at Schiphol airport (anonymous 2). A delay management procedure widely used in aviation is transporting risky passengers' bags directly to the departing flight (tail-to-tail), mentioned by anonymous 1, 2 and van Breda. Apart from delay management procedures on the ground, an airline can decide what to do when the aircraft is in the air or on the ground at its outstation. For example faster or slower flying with a lower or higher cost index resulting in a later or earlier arrival as explained by Wiegant and van Breda. Also keeping an aircraft at the outstation is one of the options, problems however could arise with the crew duty times (Wiegant).

When a ground handler is performing a turnaround they constantly update the Central Information System Schiphol (CISS), this system is monitored by all other stakeholders. Unfortunately, Pots indicates that it is almost impossible for a ground handler to plan ahead for disturbances as there is not enough manpower for this.

Van Breda mentioned a range of delay management measures and procedures used by Transavia. Operating in off peak KLM is an advantage for Transavia, but not planned around KLM fleet. Moreover for own fleet management, making it possible to increase the amount of daily flying hours. Another procedure related to the airlines' owners is that twice a day Transavia has the opportunity to have a faster turnaround operated by KLM Ground Services reducing the turnaround time with 15 minutes. As probably every airline, Transavia has crew on standby that should be able to get to Schiphol fast may there be problems with the scheduled crew. A costly measure is the use of a spare aircraft during summer months, reducing the risk of cancellation by always having a back-up aircraft. Also when the Transavia aircraft has finished the turnaround a 'ready' message is sent to the LVNL, also if this is well-before the TOBT, which could make the gate free earlier than expected.

When an aircraft arrives later or earlier than expected there are three options, the gate is free so no problems arise, the gate is not available but gate planning is able to make changes and let the aircraft taxi to an available gate or there are no suitable gates free meaning the aircraft will have to wait on a buffer stand or taxiway (Prent). Especially the last option causes congestion for the airside capacity. A solution for mitigating these situations is a 40 minute 'pit-stop' of mainly KLM aircraft, during this time the aircraft is completely unloaded and towed to a buffer to free up the gate.

4.3.4 What is in your opinion the biggest issue with the gate capacity at Schiphol airport?

After finishing the interview conversation a final statement was asked to the interviewees, asking what in their opinion the biggest issue is with gate capacity at Schiphol airport. Striking is the fact that Pots, anonymous 1 and 2, Wiegant and van Breda all mention in their own words that there has been a gigantic growth in passenger numbers while the amount of asphalt has stayed the same. Statements like 'Everything has grown except for the gate capacity' and 'Less gates while amount of flight movements has grown rapidly' are made, emphasizing the airside congestion at Schiphol airport.

Van Breda also mentions the dangerous situations that occur when having a turnaround at a buffer platform, apart from the observation that aircraft are frequently delayed by at least 10 minutes. Wiegant thinks that the biggest issue is that the gate planning department does not make use of a dynamic planning process. Prent partly confirms this statement as only scheduled times are taken into account while planning the gate distribution. It is also stated that a system is in development which calculates the predicted block times based on algorithms taking into account the historic actual times and factors such as weather, number of passengers, etc. This system however is not found A-CDM proof and therefore not used yet.

4.3.5 Additional aspects of interest

As indicated at the start of this chapter the interviews were given unstructured, therefore some other interesting aspects were found during the interviews. Pots was able to give more detail on how the TOBT is determined during a turnaround. It has been stated that there is a Service Level Agreement (SLA) between ground handler and airline which contains the Minimum Ground Time (MGT) of the airline. This MGT indicates the Off-Block Time from the moment a turnaround has started and depends on for example aircraft type. The TOBT is determined by the Turnaround Coordinator (TRC) who communicates with the flight coordinator (also from Aviapartner) and the operational personnel, using on the job training and experience he or she predicts when the TOBT should be adjusted.

Wiegant explained that the gate capacity congestion at Schiphol airport could be related to the implementation of A-CDM because aircraft wait for their TSAT at the gate, occupying the gate while being ready to depart.

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5 Research Findings

After analysing the turnaround time datasets, indicators have been found that depict the 2017 summer season gate occupancy at Schiphol airport. These indicators will be a support for the conclusion and recommendations. This chapter shows graphs with results related to the first two research sub-questions, both analysed using the quantitative data.

5.1 Strategy differences between airlines at Schiphol airport

As described in the literature review there are many differences between airlines operating at Schiphol airport. By categorizing the most important differences, a differentiation can be made between airline business models. A total of 108 airlines had scheduled operations during summer 2017 and have been identified as 56 FSNCs, 18 LCCs, 17 Freighter carriers, 11 holiday carriers, 3 regional carriers and 2 hybrid carriers as can be seen per airline in appendix X. The aircraft traffic mix has the biggest impact on the gate occupancy as wide body aircraft need more time for all ground handling processes compared to narrow body aircraft. Figure 8 below shows an overview of which aircraft traffic mix is used per airline business model, based on RECAT-EU wake turbulence categorization.



Figure 8, aircraft traffic mix per airline business model.

Figure 8 displays the aircraft traffic mix per airline business model at Schiphol airport based on RECAT-EU aircraft categories. As can be derived directly from the figure, wake turbulence category B, D and E are used far more frequently compared to categories A, C and F. FSNC at Schiphol operate virtually all aircraft categories with category D and E most frequently, aircraft in these categories are for example A320/B737 and E190 respectively. These carriers also operate the highest percentage of wide body aircraft (Cat. B) at Schiphol with about 16% of their total aircraft flight movements being wide bodies. As discussed in the literature review where it has been stated that full service carriers operate a hub-and-spoke network with smaller feeder flights which bring passengers for the wide body long haul aircraft departing from the hub at Schiphol. The largest chunk of holiday carrier flight movements are category D aircraft with almost 80 percent. Other noticeable percentages are the 13.3% for category B and 5.2% for category C aircraft, being both wide body aircraft categories this means that over 18% of holiday carrier flight movements are carried out by wide body aircraft.

Hybrid carriers and LCCs both almost only use A320/B737 (Cat. D) with 100 and 98.5 percent respectively. This can be related to the low amount of hybrid carriers at Schiphol airport as only the Norwegian family is seen as one. There are plenty of LCCs however which all use a monotype fleet, as described in the literature review, to save on aircraft costs. Regional carriers almost only fly with category E aircraft which are aircraft like Embraer 170/190, Bombardier Q400s and ATR turboprops adding up to almost 94% of all flight movements.

With the aircraft traffic mix results shown, the average scheduled and actual narrow body turnaround times are relate per airline business model. Figure 9 below contains the average scheduled and actual turnaround times in minutes for narrow body aircraft, being wake turbulence category D, E and F. Filters have been applied to exclude overnight stops. After filtering 49,291 FSNC, 1,496 Holiday, 419 hybrid, 14,589 LCC and 852 regional carrier turnarounds remained, all narrow body.

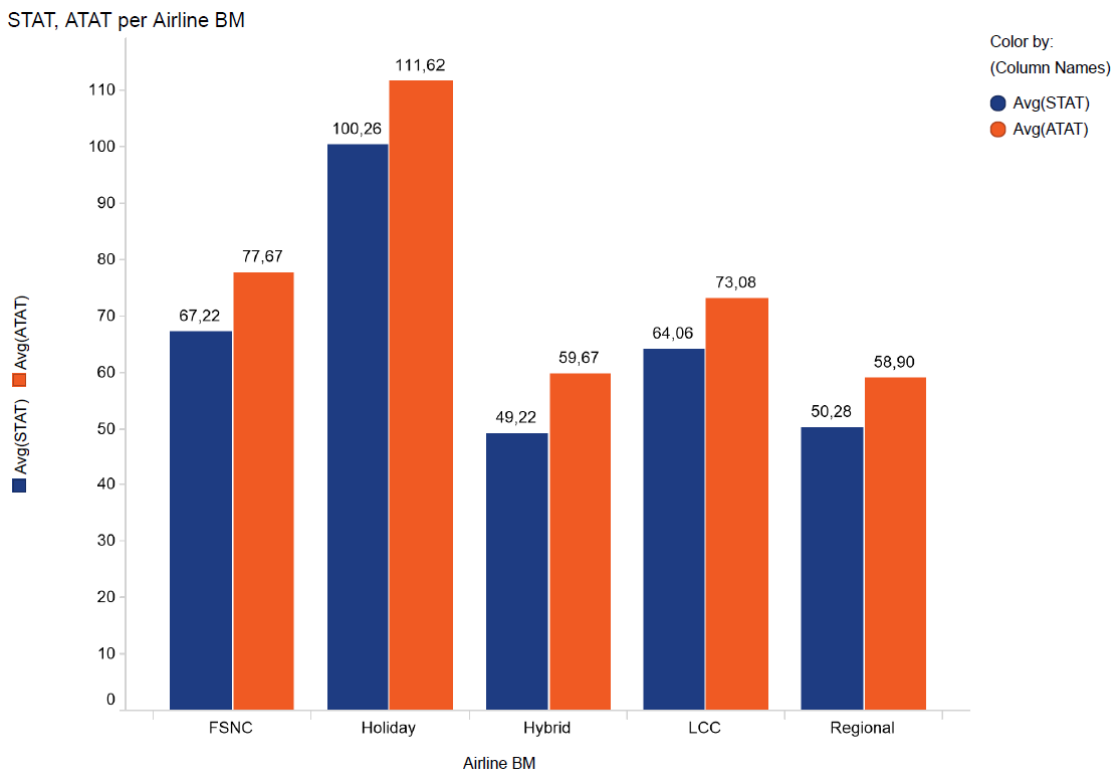


Figure 9, average scheduled and actual narrow body aircraft turnaround time per airline business model.

The average **scheduled** turnaround time for narrow body aircraft per airline business model ranges from about 49 minutes to about 100 minutes as seen in the dark blue bars. Hybrid carriers have the fastest scheduled turnaround time with on average a scheduled 49 minutes at a gate at Schiphol. This is related to the fact that only one airline is seen as a hybrid carrier, which had 419 turnarounds scheduled during summer season 2017. The relatively fast turnaround of

regional carriers at Schiphol airport is related to the smaller aircraft these carriers use for their flights, which enable faster turnarounds. FSNCs have a higher scheduled turnaround time compared to LCCs, FSNC schedule on average about 3 minutes higher turnaround time. Although it was expected that FSNC would have a higher turnaround time compared to LCC, the difference of 3 minutes was lower than expected. FSNC schedule on average 67 minutes for a turnaround while LCCs schedule 64 minutes. This is explained in the literature review which states that LCCs generally save time during their turnaround to have higher aircraft usage. The holiday carriers really stand out with the average scheduled turnaround time as they schedule about 100 minutes per turnaround at Schiphol. An explanation for this fact can be found in the interviews where Prent states that holiday carriers operate longer flights to holiday destinations and therefore need more turnaround time.

The average **actual** turnaround time for narrow body aircraft shows exactly the same distribution of airline business models compared to scheduled turnaround times as seen in the orange bars. Nonetheless, all business models have a significantly higher actual turnaround time. The regional carrier needs about 9 minutes extra compared to the scheduled turnaround time with 59 minutes per turnaround. The hybrid carrier actual turnaround time is 10 minutes higher than scheduled, climbing from 49 to 59 minutes per turnaround. The actual turnaround times increased with 11 and 9 minutes respectively to 78 minutes for FSNC and 73 minutes for LCCs on average. Holiday carriers stay having a high turnaround time compared to all other business models with an average of 112 minutes compared to an average scheduled turnaround of 100 minutes. As discussed in the interviews, Prent stated that according to the RASAS guidelines 95% of all turnaround at the low cost H-pier should be below 30 minutes. However, with both scheduled and actual turnaround times for LCC being far above this amount of time it seems that this guideline is not followed during daily operations. Prent further states that these turnaround times are not monitored or penalized when exceeded by the airline, which is an explanation for the higher LCC turnaround times.

Of all wide body turnarounds 9,681 FSNC, 321 holiday and 10 LCC carrier turnarounds remained after filtering overnight stops. Because of the low amount of wide body LCC turnarounds, these are excluded from the results.

STAT, ATAT per Airline BM

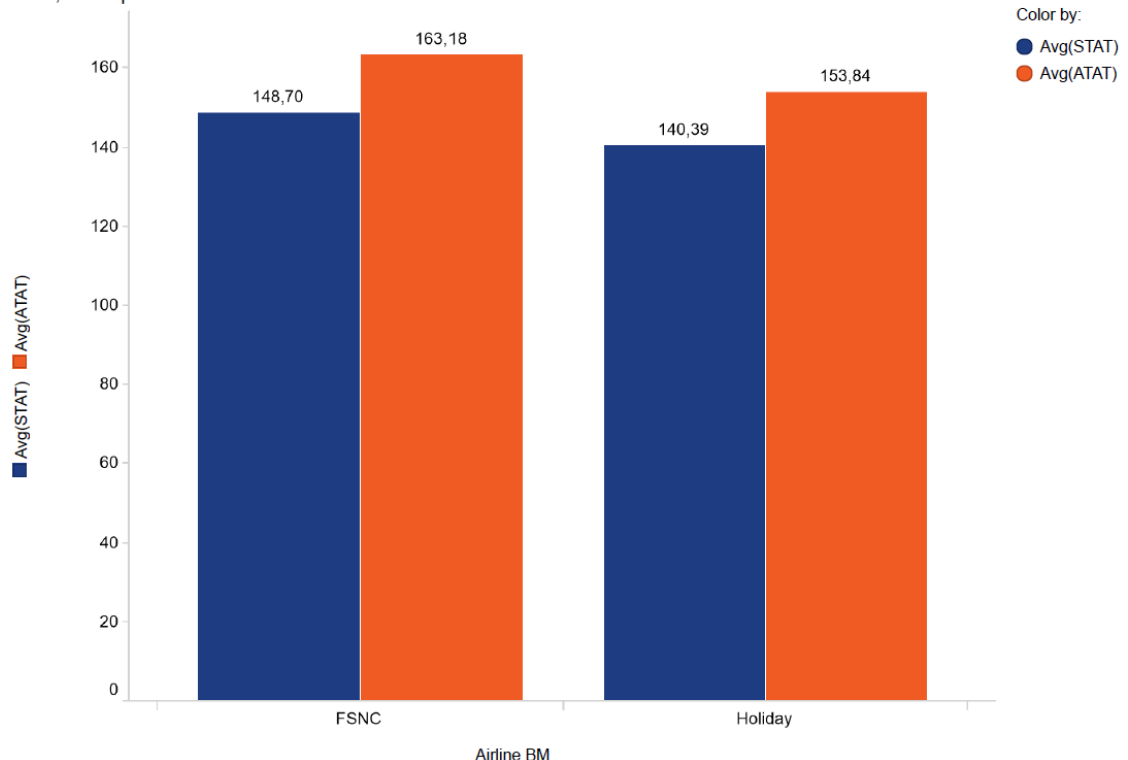


Figure 10, average scheduled and actual wide body aircraft turnaround time per airline business model.

Wide body aircraft have long turnaround times than narrow body aircraft because ground handling processes take longer when the aircraft is larger. This is also derived from the average

scheduled and actual turnaround times of all wide body aircraft at Schiphol airport. As can be seen in figure 10 only two airline business models operate wide body aircraft; FSNCs and holiday carriers. The average **scheduled** turnaround time for FSNC wide body aircraft is 149 minutes or 2 hours and 29 minutes while holiday carriers carry out wide body turnarounds in 140 minutes or 2 hours and 20 minutes. As mentioned in the literature review FSNC operate a hub-and-spoke network from their base while holiday carriers only have point-to-point flights, this is an explanation for the average 9 minutes' difference in turnaround time.

As with the narrow body aircraft average turnaround times, the **actual** wide body average turnaround time shows the same distribution. Figure 10 shows that FSNC have an average actual turnaround of 163 minutes, being 14 minutes longer than scheduled and thus still on-time according IATA standards. Holiday carriers have an average wide body actual turnaround of 154 minutes which is also 14 minutes longer compared to the average scheduled turnaround time. It seems that like the narrow body turnarounds, the wide body aircraft have longer turnarounds. Explanations for the difference in scheduled and actual turnaround times are the implementation of A-CDM, no show of passengers or a lack of resources for ground handlers during the peak flight movement hours at Schiphol as displayed in the interviews.

5.2 Impact airline strategy differences

At Schiphol there are eight passenger piers, currently the A-pier is under construction and only used as an apron for regional aircraft where passengers are transported by bus. The B and C aprons are only used for narrow body aircraft of all airline business models while the D apron has a mixed configuration of both narrow and wide body aircraft. The E and F gates are specifically designed for long-haul wide body aircraft, the G apron is mainly used by airlines flying to and from non-Schengen destinations. The H pier at Schiphol is a dedicated low cost terminal with a limited amount of services providing the best fit for LCCs.

The difference in turnaround times between all airline business models can be related from the turnaround distribution categorised per terminal pier at Schiphol airport. The turnaround data has been combined and resulted in a total of 75,988 aircraft turnarounds at the main airport piers during summer season 2017, seen in figure 11 on the next page.

The box and whisker graph shows the time variation distribution between scheduled and actual turnaround time as discussed in paragraph 2.3.1. Seen is that pier B, C and D have an almost identical distribution because these piers almost only have narrow body aircraft turnarounds of various airline business models. The A pier has a somewhat higher distribution of turnaround time delay, meaning that regional aircraft have a higher turnaround than scheduled. The E, F and G piers show a wide distribution because of the lower amount of turnarounds, these piers are designed for large aircraft and therefore have a lower amount of gates. The H-pier distribution clearly shows that LCCs are better in handling the aircraft as scheduled as it has the least turnaround time delay of all airport piers.

Apart from the turnaround time delay distribution, figure 11 also contains the average turnaround time delay and standard deviation of this turnaround time delay per pier. The average turnaround time delay ranges from 8 minutes at the H-pier to 17 minutes at the E-pier. Related to the fact that only LCCs narrow body aircraft are handled at the H-pier while the E-pier only sees wide body FSNC operating.

As shown in the table below figure 11 there is high variation and therefore a high standard deviation in the average turnaround time delay per airport pier. Ranging from a 30 minutes decrease in turnaround to a 60 minute increase all airport piers show results across this timeframe. This is also derived from the outliers, showed as point, as they continue as almost a straight line even when the upper- or lower fence of the boxplot ended. This high variation in turnaround delay values means that it is hard to predict upfront whether the actual turnaround time will be shorter, the same or higher compared to the scheduled turnaround time. This is also an indicator that there is not a specific reason for turnaround time delay as values are widespread across the spectrum. Multiple aspects can delay the turnaround process like late passengers, technical difficulties, en route weather changes, etc. All these aspects have a different impact on the turnaround time delay.

Box Plot

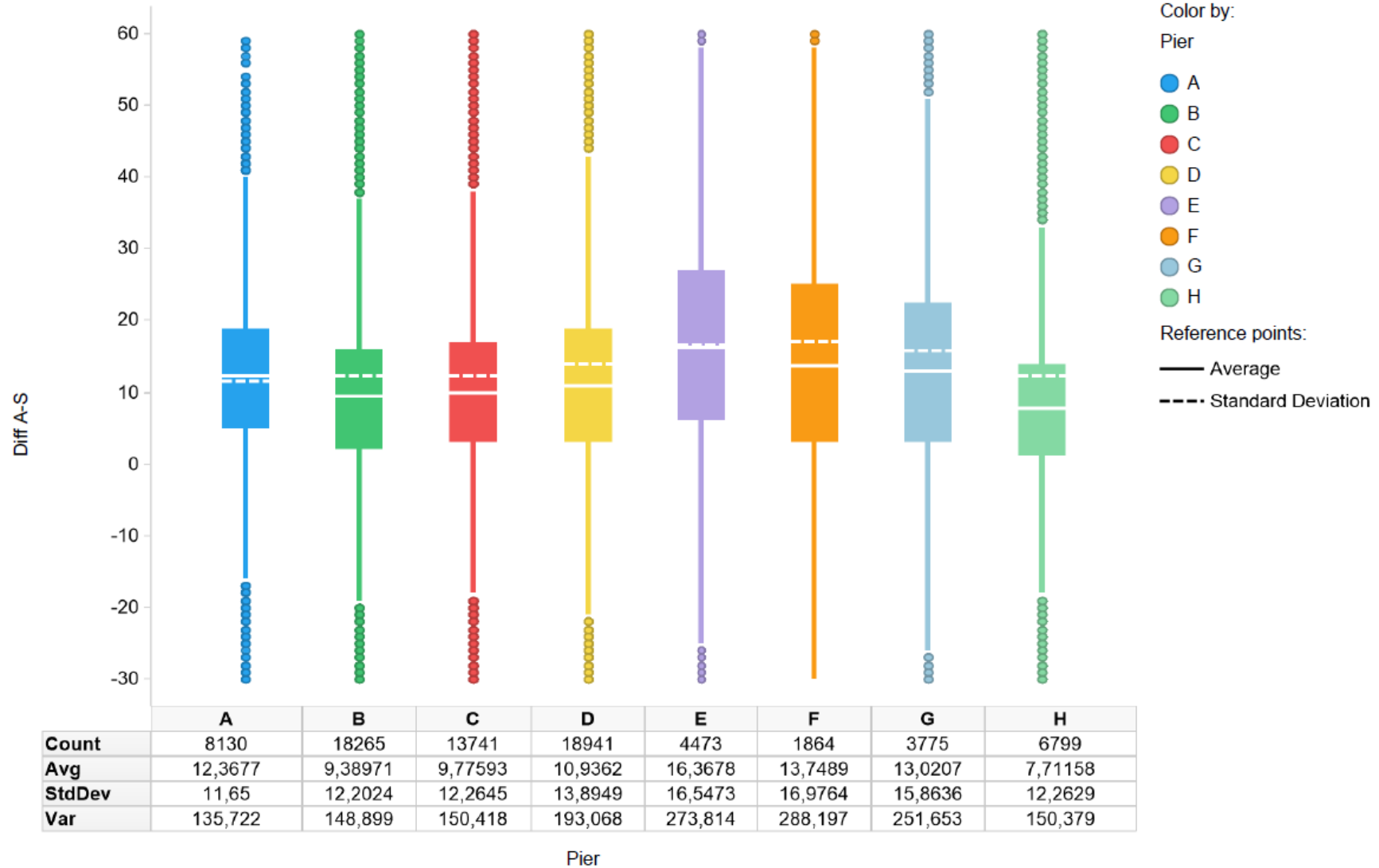


Figure 11, box plot of turnaround time coherence per Schiphol airport pier.

The average time difference between actual and scheduled turnaround time for narrow body aircraft per airline business model is seen in figure 12 below. A total of 66,647 NABO turnarounds have been carried out in this timeframe of which 49,291 FSNC, 1,496 Holiday, 419 hybrid, 14,589 LCC and 852 regional carriers.

It shows that the average turnaround time delay per airline business model is very close to each other as the maximum difference is only about 3 minutes. The business model with the least turnaround time delay are the regional carriers LCCs with under 9 minutes longer at a gate than scheduled. This does not differ much with the LCCs as they have an average turnaround time delay of just over 9 minutes. FSNCs and hybrid carriers have similar turnaround time delays with both about 11 minutes of extra time at the gate. As with the average scheduled and actual turnaround the holiday carriers have the highest value, their turnaround time delay is over 11 minutes.

Contrary to the hypotheses the result show that there is not much difference in the average turnaround time delay per airline business model. Aircraft operators across all business models are on average about 10 minutes longer at the gate than scheduled. Summer season 2017 consisted of 218 days, with 66,647 turnarounds being on average 10 minutes turnaround time delay meaning that 3,000 extra minutes or 51 extra hours per day must be scheduled at the gate planning department of Schiphol on average.

Diff A-S per Airline BM

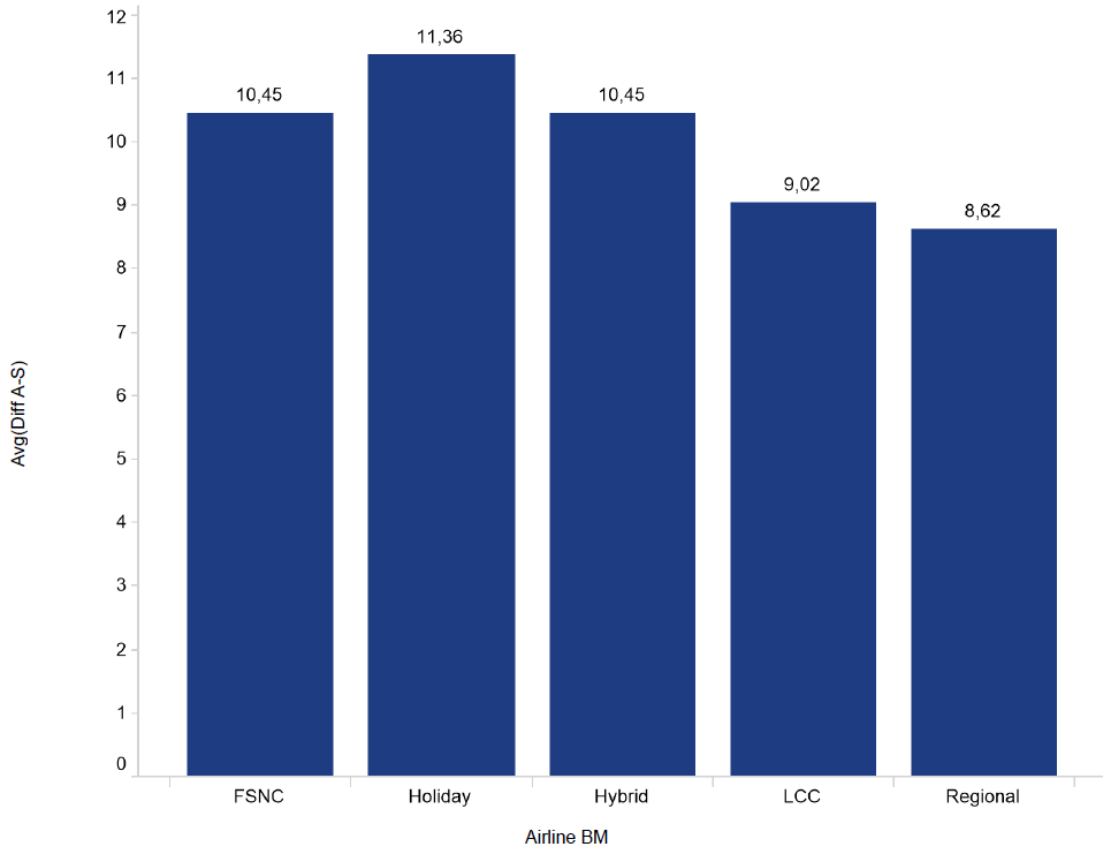


Figure 12, average NABO turnaround time delay per airline business model.

To put the distribution of all narrow body turnaround time delays in perspective a box and whisker graph is seen in figure 13 on the next page. This graph contains the same data as figure 12. Seen is that the holiday carriers have a much wider distribution compared to other business models, which is related to the total amount of turnarounds. However there was fewer data for regional carriers while the distribution is similar to that of LCCs and FSNCs which is the other remarkable item of the graph. On average FSNCs and LCCs have virtually the same distribution of all turnaround time delays.

As with the airport pier the variation in turnaround time delay is high across all airline business models. Again most outliers continue as a straight line when the upper- or lower fence of the boxplot has ended. The high variation would mean that turnaround time delays are hard to predict. However, as seen in figure 12 the average turnaround time delay differs only 3 minutes between all narrow body airline business models. Reason for this would be that an airline can be delayed for multiple reasons and that both airline business models have more or less the same reasons for their turnaround time delay.

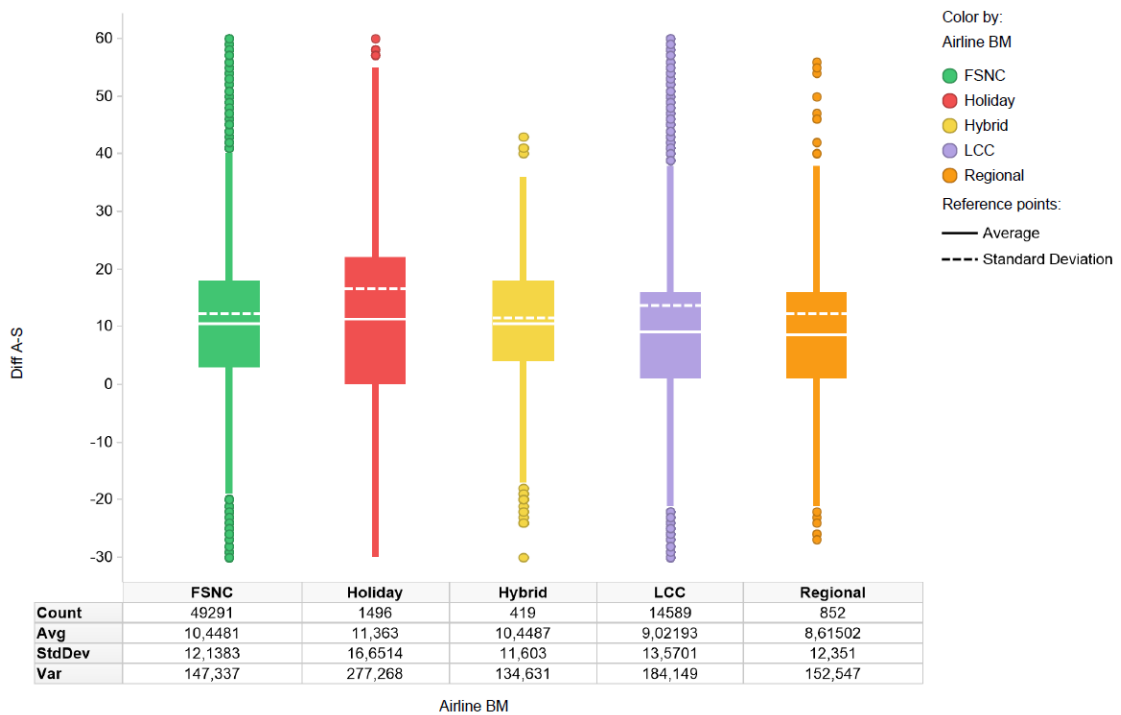


Figure 13, boxplot of narrow body turnaround time delay per airline business model.

As showed in the results there is only a slight difference between airline business models and their average turnaround time delay. However, for a good understanding of this fact the average turnaround time delay of FSNCs and LCCs is shown in figure 14 related to the hour of day the turnaround took place.

As can be seen the difference in minutes between scheduled and actual turnaround ranges between 4 and 12 minutes depending on time of day and business model. The green line clearly shows that in the morning FSNC have on average a higher turnaround time delay compared to the afternoon. The LCCs shown in purple have a bigger distribution throughout the day but generally stay underneath the FSNC turnaround time delay. Interesting to see in the graph is the relatively low turnaround time delay for FSNC between 9AM and 11AM while LCCs tend to have higher actual turnarounds during the same timeframe. Possible explanation is the taxiway congestion as the H-pier is not accessible when a wide body aircraft arrives or departs from the G-pier, causing congestion for the LCCs as described in the literature review. The FSNC turnaround time delay gradually descends throughout the day, except for a peak at noon. This gradually descending line may be explained by the catching up of reactionary delay gained during the morning.

Overall the turnaround delay stays about the same for both business models, this is also seen in the total average as these differ only 2 minutes between FSNCs and LCCs.

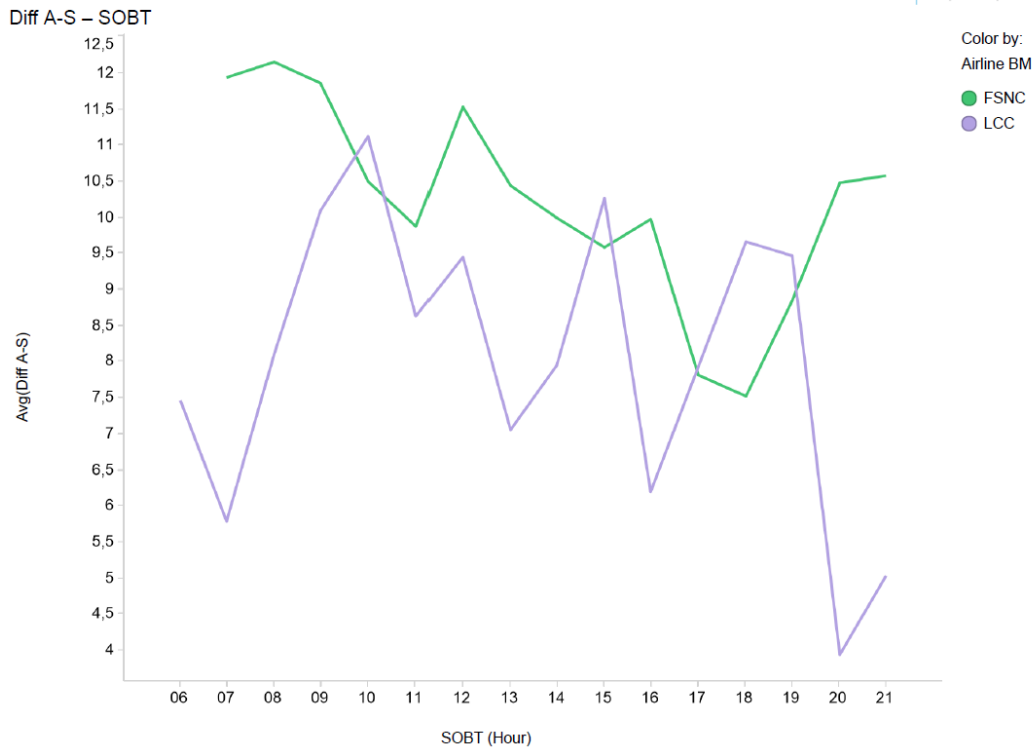


Figure 14, turnaround time delay FSNC and LCC narrow body per SOBT.

The turnaround time delay differences of wide body aircraft have also been researched. Of all wide body turnarounds 9,681 FSNC, 321 holiday and 10 LCC carrier turnarounds remained after filtering overnight stops. Because of the low amount of wide body LCC turnarounds, these are excluded from the results. The box and whisker graph in figure 15 shows the distribution of turnaround time delay between FSNCs and holiday carriers.

More time is scheduled for wide body aircraft as their turnaround time is higher. However, this scheduled time is not enough for the turnaround to take place as the scheduled turnarounds are exceeded by on average 14 minutes. Figure 11 already showed that the airport piers for wide body aircraft (E, F and G) had the highest turnaround time delay and variance. The comparison below however shows an even higher variance.

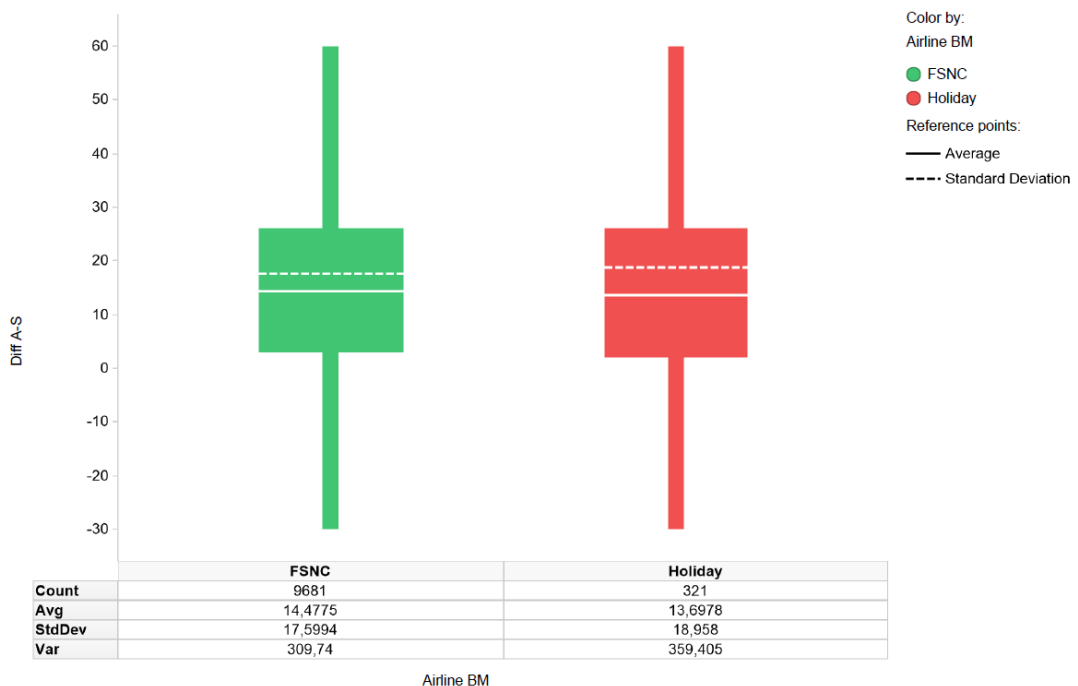


Figure 15, boxplot of wide body turnaround time delay per airline business model.

This higher variance means that the turnaround time delay distribution of wide body aircraft is even more spread compared to narrow body aircraft. An explanation is the lower amount of data which causes the boxplot to contain values over a higher distribution. Another explanation are the endless possible reasons for a delayed or earlier departure. Upfront it is hard to predict how much longer or shorter an aircraft will stand at the gate.

At Schiphol airport all wide body aircraft operators can be divided into base and non-base carriers. A list of all base carriers can be found in paragraph 4.2. A comparison between base and non-base carriers wide body aircraft turnaround time delay can be seen in figure 16. The blue line represents the base airlines while the grey line indicates the non-base carriers. Clearly found in figure 16 is that non-base carriers achieve far better in complying with the scheduled turnaround time. The figure shows that base carriers during some hours have delays of at least 16 minutes while the non-base carriers mostly stay underneath a 10 minute turnaround time delay. This is related to all transfer passengers that travel via Schiphol airport. Base carriers usually carry more transfer passengers as their hub is where passengers have their transfer. It has been identified during the interviews that these transfer passengers sometimes cause a delay at base carriers because they arrive late for their connection. A possible consequence for late arriving passengers is that their bags have to be offloaded from the aircraft.

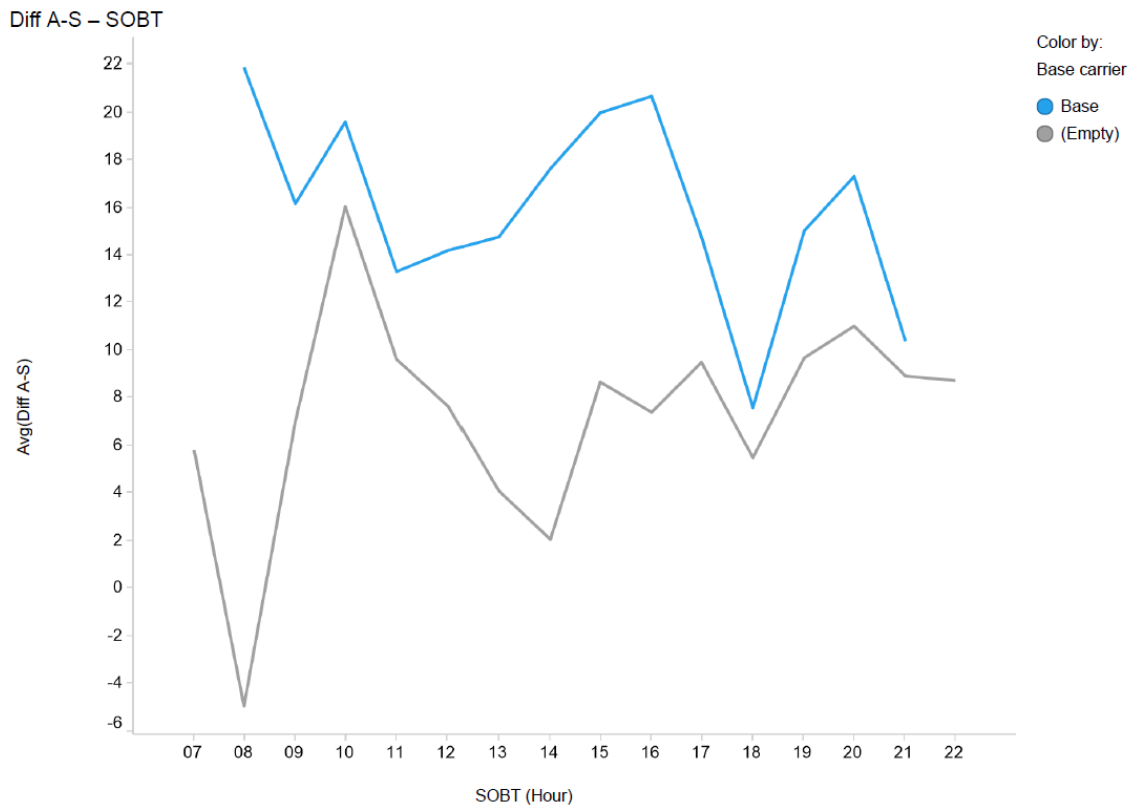


Figure 16, turnaround time delay base/non-base carrier wide body aircraft per SOBT.

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6 Conclusions

The actual turnaround times are longer than scheduled turnaround times, especially for base carriers. The main research question: **‘How do airline characteristics, ranging from business model differences to variation in actual procedures, affect AAS gate capacity?’** has been answered using literature research, quantitative data and interviews with key stakeholders. These sources are combined for answering the research question, first the conclusion for all sub-questions will be discussed after which the entire research is concluded.

6.1 Strategy differences between airlines at Schiphol airport

The first sub research question concerned the airlines operating from and to Schiphol airport: **‘What are the strategy differences between passenger airlines operating at AAS?’**. To answer this question all passenger airlines have been categorized using literature research and applicable variables, resulting in a detailed list of every airline.

Differences that have an impact on the gate capacity are traffic mix, turnaround time, network type, hold baggage policy and aircraft utilisation. FSNCs have a wide range of aircraft types in their fleet while LCCs mainly operate a single type fleet, also hold luggage has to be paid for with LCCs.

The scheduled and actual turnaround times have been derived from a combined dataset. It turned out that LCCs had a higher than expected scheduled turnaround time at 65 minutes, an increase of 30 minutes compared to the 35-minute guideline at the H-pier. As expected FSNCs had a turnaround time of around an hour. Holiday carriers really stood out with their turnarounds as they schedule on average almost 100 minutes per turnaround. The results of the actual turnarounds showed that these are longer by about 10 minutes for every airline business model.

To summarize a total of 6 airline business models have been identified, each of these contain different characteristics for the airline. The 91 passenger airlines at Schiphol therefore are categorized in FSNC, LCC, holiday-, regional- or hybrid business models. The average narrow body aircraft scheduled turnaround time varied between 60 minutes for FSNCs to almost 100 minutes for holiday carriers.

6.2 Impact airline strategy differences

The second research question aimed to get insight into the impact of all different airline structures at AAS: **‘What is the impact of airline structures and airline traffic mix on gate occupancy of AAS?’**. Using quantitative data the time difference between actual and scheduled turnaround times has been calculated. This time difference is directly involving the gate occupancy as no aircraft can use a gate while it is occupied by another.

Multiple categorizations have been made to find answers on the research question. Aircraft type, flight duration, airline characteristics and pier used for turnaround have all been part of the calculations. The E, F and G pier have a higher turnaround time delay distribution related to all wide body aircraft serviced at these piers, showing that these aircraft have higher turnaround time delay. Also the distribution for these piers were higher, meaning wide body aircraft depart both well before and well after schedule. The average narrow body actual turnaround time turned out to be 10 minutes longer for every business model, resulting in a higher gate occupancy with the same amount of turnarounds. For wide body aircraft this has been about 14 minutes.

Interesting is the fact that there is not much difference between airline business models and average turnaround time delay while this was expected. Only when comparing between business models and scheduled off-block time (SOBT) the results showed that LCCs mainly stay below the FSNC turnaround time delay throughout the day. The difference between base- and non-base carriers did also result in turnaround time delay differences. Base carriers have a higher turnaround time delay throughout the day compared to non-base carriers for both narrow- and wide body aircraft. Especially wide body aircraft showed a difference between base and non-base carriers as non-base carriers have a constantly lower turnaround time delay.

To answer the research question the airline structures all have a higher average gate occupancy, impacting the gate occupancy of AAS. This higher gate occupancy is the result of longer actual turnarounds, caused by various reasons like hold baggage that has to be offloaded, transfer passengers that are late or a lack of resources with the ground handling.

6.3 Gate capacity experiences

To know what the reasons are for delay or early arrival at the gate the third sub research question has been created: **‘What delay recovery techniques are used by airlines at AAS and what is their impact on the airside capacity of AAS?’**. Interviews with six stakeholders have been kept. These interviews were given unstructured so the interviewees had the freedom to speak about their concept of the gate occupancy or any other relevant subject. Five questions relating to the gate capacity and delay management measures have been set up to guide the interview in the right direction.

The interviewees discussed interesting aspects of the turnaround time, gate occupancy and gate capacity at Schiphol airport. All participants agree that the amount of flight movements at Schiphol has been growing while the amount of gates did not, actually for the 2018 summer season 16 extra aircraft stands had to be created. The KLM flight coordinator helps with the gate planning as they provide the Schiphol gate planning department with detailed information. The implementation of A-CDM however, did not result in better gate occupancy as aircraft wait for their Target Start-up Approval Time (TSAT) at the gate.

Multiple reasons are explained for which an aircraft could be delayed at the gate for other than airline/ATC related delays. Aircraft crew can show up late, bags could have to be unloaded because of a passenger not showing up, technical difficulties could arise and there is a lack of resources for servicing the aircraft during the morning peak. Ways to prevent these delays are having a spare aircraft, scheduling longer turnaround times or improving ground handling awareness by implementing the ‘PLUG’ app. This app shows all separate handling processes where the supervisor of the specific process can fill in when the process was started resulting in an earlier and better TOBT estimation.

To conclude it turned out that most interviewees are agreeing there is a gate capacity shortage at Schiphol airport. The turnaround time delays are caused by multiple stakeholders for multiple reasons. To cope with this extra gate occupancy both pro- and reactive delay management techniques are used which have a positive impact on the gate capacity. Examples of these techniques are having a spare aircraft, scheduling reserve crew and varying the speed of the aircraft while flying resulting in an earlier or later arrival.

6.4 Overall conclusion

When adding up all conclusions, the main research question can be answered: **‘How do airline characteristics, ranging from business model differences to variation in actual procedures, affect AAS gate capacity?’**. The answers to this question are pictured in figure 17, showing an Ishikawa diagram of which aspects influence the turnaround time delay.

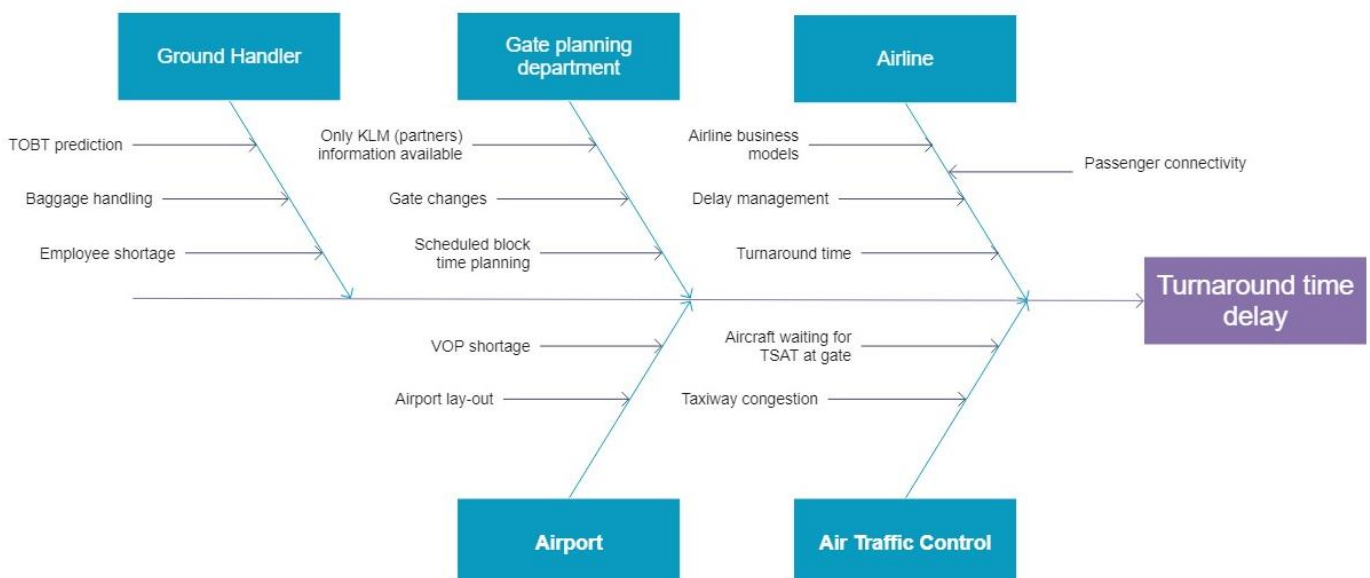


Figure 17, Ishikawa diagram of conclusions.

Ground handlers cause turnaround time delay because of personnel shortage or indirectly by predicting an incorrect TOBT. The gate planning department has only flight information of KLM and its partners while gate changes may lead to higher turnaround times. The airport suffers from an aircraft stand shortage as every summer the buffer stands are needed for turning around aircraft. Aircraft can be delayed at the gate because of their assigned TSAT, causing congestion at the airport. All airlines are categorized in business models with various characteristics such as traffic mix, turnaround time and passenger type. The differences between average turnaround times turned out high as hybrid airlines only need 50 minutes while holiday carriers need at least 100 minutes. The turnaround time delay however, turned out small as all aircraft have a longer turnaround of on average 9 to 15 minutes. Therefore this research concludes that the Schiphol gate occupancy is affected by multiple stakeholders who are all part of the turnaround process of every aircraft.

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7 Discussion

Whereas the conclusion contained concise answers on all research questions, this discussion will elaborate on the evaluation of the research. The interpretation section emphasizes on the validity of the research, all research limitations are discussed and recommendations for further research are given. Furthermore, the connections between other KDC research topics are explained.

7.1 Interpretation

Research has been conducted in the area of gate occupancy and airline business model differences. As this literature review would be the base of the research much attention was focused on completing this part. The literature research gave answers on which general airline business models exist and how they operate. Full Service Network Carriers (FSNCs) operate a hub-and-spoke network where passengers travel to their destination via the carrier's hub. These carriers traffic mix comprises both regional feeder aircraft and long-range wide body aircraft. Low Cost Carriers (LCCs) aim to have the lowest expenses possible by increasing aircraft usage and using secondary airports. For further cost reduction a mono-type fleet is operated for point-to-point routes. Holiday carriers mainly focus on transporting tourists to seasonal holiday destinations, frequencies differ as most people tend to go on holiday for 1 or 2 weeks. Airlines that fly with small aircraft in a particular area or region are seen as regional carriers. Many of these carriers operate for FSNCs to connect their hub with regional airports, when operating on its own it uses characteristics of LCCs. Hybrid carriers are operating between the discussed models, using characteristics of multiple types of airlines.

A total of 91 passenger airlines had scheduled operations during summer season 2017, identified as 56 FSNCs, 18 LCCs, 11 holiday carriers, 3 regional carriers and 2 hybrid carriers. Of all these airlines 3 FSNCs, 2 LCCs, 1 freighter carrier and 2 holiday carriers have aircraft based at Schiphol.

When writing the research plan, a hypothesis was stated on what the expected differences are of airline business models related to the gate occupancy. It was expected that FSNCs had a higher turnaround delay because of their transfer passengers while LCCs would want to follow the scheduled times for achieving higher aircraft usage. Furthermore, regional carriers should have lower turnaround times because their aircraft mix consists of small aircraft. Holiday carriers are expected to share operational similarities with LCCs, having short turnarounds to increase amount of daily flight hours.

For finding out the validity of above mentioned statements, a quantitative data source was searched and found in the local A-CDM data. This data contains all A-CDM milestones including block times, these times represent when the aircraft turnaround started or ended. First a sample of one month was researched before applying the same techniques to a dataset containing the complete summer season of 2017. This timeframe was chosen because during summer Schiphol has to cope with more traffic which results in a tighter gate planning schedule.

Multiple categorizations have been made to find answers on the research question. Aircraft type, flight duration, airline characteristics and pier used for turnaround are all part of the calculations. The results showed that a clear correlation can be seen between pier of operating and turnaround time delay. The distribution of all eight piers and their turnaround time delays showed that the wide body piers of E, F and G had more turnaround time delay, resulting in a higher gate occupancy and thus creating congestion. The low cost H-pier showed a much lower distribution, showing that on average LCC have less turnaround time delay.

This is also derived from the average narrow body turnaround time delay per airline business model where LCCs have the lowest difference between scheduled and actual turnaround time with 9 minutes. On average FSNCs have a 11 minutes longer turnaround time while holiday carriers have an average extra turnaround time of almost 12 minutes. The turnaround time delay of FSNC and LCC narrow body aircraft is also related to the scheduled departure time of the flight. This relation shows that FSNC start the day with a high turnaround time delay of 12 minutes and then gradually descends to 7 minutes at the end of the day. LCCs however, have more ups and downs starting with 6 minutes but rising fast to 11 minutes at around 10AM. Reasons for this can be found in the bottleneck at the GH-bay where no aircraft can enter or depart when a wide

body aircraft is pushed back. This is the cause for the congestion as the wide body aircraft movements' peak is between 9AM and 11AM.

Also the difference between base carriers and non-base carriers is clear when looking at the results, base carriers have for both narrow- and wide body aircraft a longer turnaround time delay. The comparison between narrow body, base and non-base carriers, turnaround time delay and scheduled departure time shows that non-base carriers have a lower turnaround time delay compared to base carriers throughout the day, except for a peak at 3PM. The same comparison with wide body aircraft shows that base carriers stay having a higher turnaround time delay compared to non-base carriers. These differences are related to the transfer passengers as the home base carriers have their hubs at Schiphol and therefore many connecting passengers. A late arrival of these passenger causes trouble as the bag might be already in the aircraft while the passenger does not enter the flight, meaning the bag has to be removed again.

For putting all Schiphol stakeholders' view on the gate capacity in perception, interviews are kept with six people. A total of five questions have been asked relating to the gate occupancy and gate capacity at Schiphol airport.

First topic of interest has been the gate capacity at Schiphol and possible impacts on the operation of the stakeholders. All but one interviewees emphasized that there is a gate shortage at Schiphol because the increase in flight movements in the past years did not result in additional gate capacity. A temporary solution that seems more or less permanent is the use of buffer platforms for turnarounds, causing problems for several stakeholders. The KLM flight coordinator is seen as very positive, helping the gate planning department of Schiphol with better information on KLM and its partner's flights. The implementation of A-CDM did cause some problems for the gate capacity as it occurs that aircraft have to wait at the gate for their Target Start-up Approval Time (TSAT).

Secondly the interviewees were asked whether their airline or customer is delayed at the gate for other than ATC/airport related delays. This resulted in both reasons for which airlines stay longer at the gate than scheduled and for which not. It was expected that transfer passengers would cause turnaround delays for FSNC as this group of passengers is vital for them. However two interviewees working with a FSNC stated that this carrier does not wait for transfer passengers. Indirectly this group of passengers can still cause a delay because of the baggage transfer. When the transfer passenger does not make it to the flight the bag has to be un-loaded, resulting in more time at the gate for the aircraft. It has also been stated that during the 'peak of the peak' (roughly 15 minutes between 8AM and 11AM) extra personnel could be used for servicing turnarounds. These are not hired however as these employees have to be hired for a minimum of three hours. Mentioned by all airline employees is the fact that a technical difficulty can occur and result in a higher gate occupancy.

To find out what delay management measures are used by the interviewees for mitigating delays, question three has been asked. The Schiphol interviewee mentioned there are three options for the gate planning when an aircraft arrives early or late. The gate is free, the gate is occupied but changes can be made to accommodate the flight or there is no suitable gate available meaning the aircraft has to wait on a buffer stand or taxiway causing congestion. A way to avoid this congestion is to operate outside the flight movements peaks, as Transavia does. Another development is accommodating shorter turnaround times by applying new methods such as boarding and de-boarding using both front and aft stairs at a gate. In the future less delays should occur because of the implementation of the 'PLUG' app, resulting in better awareness of all ground handling stakeholders.

To wrap up the interview a last statement has been asked regarding the interviewees' biggest issue with gate capacity at Schiphol airport. All mentioned that they feel there has been a huge growth in flight movements which is not seen in the number of aircraft stands. Furthermore currently the gate planning is not dynamic, resulting in constant gate changes. Also dangerous situations occur during buffer handling apart from a constant delayed departure.

The statements have also been correlated with the data analysis results, between which a clear relation was found. For example the fact that turnarounds are delayed longer during the flight

movement peak of Schiphol in the morning. This result derived from the data is explained by the personnel shortage at the ground handlers during the peak, according one of the interviewees.

To finalize this discussion the research showed that the hypothesis was partly wrong about the presumed results. It has been proven that the FSNCs do have a longer turnaround time delay compared to LCCs, the difference however is only 2 minutes per turnaround. Another interesting fact is seen in the average scheduled turnaround times which shows that FSNCs on average schedule less time for a turnaround while their actual turnaround times are on average higher than LCCs. As expected the regional carriers had the lowest scheduled and actual turnaround time because of their small aircraft, therefore it can be concluded that aircraft mix does have an influence on both average turnaround time and average turnaround time delay. The expectation was that holiday carriers shared operational similarities with LCCs and would have a low turnaround time as well as a low turnaround time delay. The results showed that this expectation is not valid as holiday carriers had the highest turnaround time and turnaround time delay compared to all other narrow body aircraft business models. Explanation for this fact can be found in the fact that baggage has to be off loaded when a passenger does not enter the aircraft on-time. This process takes time for the ground handler and often leads to a higher than scheduled turnaround time.

7.2 Limitations

For this research there were not much limitations, mainly thanks to the KDC cooperation between Schiphol, LVNL and KLM which all contributed to the results. As mentioned the LVNL could not provide all needed data for the research, therefore extra data has been asked and provided by Schiphol. For this research only Schiphol data was needed.

The data samples both consisted of A-CDM data between 26th of March 2017 and 29th of October 2017, the summer season of 2017 according to IATA. This data was used because the gate capacity is congested, especially during summer when more flights are executed. Because of this reason a qualitative research has been conducted however, the impact of airline business models on the gate occupancy during winter season has not been researched.

Unfortunately some categorizations provided limited amount of data and therefore are excluded from the results. For example LCCs that had only 14 wide body aircraft turnarounds during summer season 2017 or Norwegian that is seen as the only hybrid carrier.

7.3 Further research

As stated in the conclusion, further research is needed to compare the flight delay codes with the turnaround time delay, resulting in better understanding on why the turnaround time took longer than scheduled. The Eurocontrol department Central Office for Delay Analysis (CODA) monitors all delay reason of flights to and from Europe, categorized per IATA delay codes (CODA, 2018). This data is brought out monthly using a report, not specifying what the exact delay reason was for a specific flight. This data should somehow be related to the data already researched and searched for correlations between any other variable used for this research.

The literature research contained a formula which is the work of Mirkovic and Tomic (2017), this formula calculates the apron capacity of an airport using values related to the airport (Mirkovic & Tomic, 2017). Unfortunately it turned out that the timeframe was too tight to include this formula in all gate occupancy calculations. This formula would create a good overview of what the theoretical and actual apron capacity is based on movements per hour. This apron capacity could then be related to the runway capacity to find out whether there is a mismatch between these capacities.

Another interesting further research topic is the timeframe of the data. For this research the summer season of 2017 has been researched, other timeframes that would be interesting to correlate are the winter season, other recent (or past) years or a complete year. Especially during winter season some aircraft stands are permanently occupied for de-icing operations to take place.

As the KDC Mainport focuses on sustainable developments at Schiphol airport, this research has focused on this airport. However, other airports that have a congested gate capacity might be interested to research what the exact impact is of airline business models on their gate capacity. This could be any airport in the world as more and more business models differentiate, providing unique characteristics for airports to keep in mind.

The research plan, results and all other relevant information has been documented throughout the analysis. This documentation can be used by every future KDC-student.

7.4 Connection with other KDC research topics

This research was conducted simultaneously with five other Amsterdam University of Applied Sciences (AUAS) students, all performing a research to gain insight into several aspects of capacity management. Roel Wouters researched the actual result of implementing local A-CDM at Schiphol airport, his aim was to find out whether the on time performance has been improved since implementing (Wouters, 2018). Contrary to his expectations the on time performance continued to move downwards when A-CDM was implemented. This fact is also related to the turnaround time delays as mostly when a turnaround takes more time than scheduled, the aircraft does not depart on time. Both this and Roel's research have used the same datasets, Roel however compared the on time performance over multiple years instead over one season. Identifying all airside capacity bottlenecks of Schiphol was the aim of the research of Gijs Peters (Peters, 2018). By interviewing a wide range of stakeholders, focussing on KDC members, he identified many airside bottlenecks and the related impacts per stakeholder. One of his findings is that Schiphol has a lack of gate capacity, resulting in congestion on taxiways and delayed flights. These two mentioned researches have the most in common with this research.

Bas Broekstra aimed to find out what the impacts are of special events on the airspace capacity around Schiphol airport (Broekstra, 2018). By identifying all steps needed for planning special events like the Tour de France, Nuclear Security Summit and military exercises he mapped the process and interviewed stakeholders involved in the planning process. He concluded that the communication between all parties involved in planning and executing the special event is not optimal, causing last-minute changes which in turn may lead to extra congestion in the airspace. Another interesting research has been conducted by Marc Eijkens as he researched the effect of climb restrictions for flights departing Schiphol airport (Eijkens, 2018). He found out that many flights departing Schiphol have climb restrictions and have to level off at a certain less efficient flight level, causing more fuel consumption for the airlines. Last but not least Megan Heijke researches the data link opportunities for the KDC stakeholders, looking for IT-innovations in the aviation industry that can improve predictability. More and more modern aircraft fly around the world with the possibility to share data through satellites with the ground. A major benefit would be predicting when the aircraft enters Dutch airspace, making resource planning more efficient for both ATC and airport.

At the moment Frenchez Pietersz is analysing above mentioned and more research to show all correlations between the research and the current operations at Schiphol airport.

Apart from above mentioned researches conducted by AUAS students, KDC Mainport also outsources several researches to consulting companies. All this research has the aim to find valuable and innovative solutions for sustainable developments of Mainport Schiphol.

Two researches have already been mentioned in this report: managing turnaround priorities and a benefit analysis of RECAT-EU wake turbulence categorization for Schiphol. The turnaround priorities research concluded that there is no shared view of gate management challenges or solutions amongst all different stakeholders. The recommendations of this research included introducing a new outbound planning tool, sharing gate management information and developing a set of rules on gate management that have to be followed. These conclusions and recommendations are somewhat similar to this research, as can be related with the interviews. By following previous and future recommendations Amsterdam Airport Schiphol will be able to apply innovative solutions for sustainable developments at the airport.

8 Recommendations

As described in multiple future capacity predictions for Schiphol airport, like ATM2020+, there is a lack of aircraft stands and gates (LVNL, 2018). Therefore, the use of these stands and gates must be optimized in order to enable a more robust planning. Together with the literature research, quantitative analysis and interviews the impact of airlines on the gate occupancy at Schiphol airport has been identified. Based on these impacts recommendations have been drawn per stakeholder:

- Ground handlers
- Airport
- Airlines
- Air Traffic control

According to the work of Conway (2018) there is a 'race to the bottom' going on between all ground handlers, stating that "Sustainable profitability will be a challenge, particularly as the airline customers also struggle with that," (Conway, 2018). Because of this reason, ground handlers plan their operation with as low resources as possible to reduce costs. A disadvantage however is that a personnel shortage may lead to longer turnaround times, as correlated between the interviews and quantitative analysis. To gain more insight in this aspect, the shortage should be identified and searched for solutions. Furthermore, innovative solutions like the discussed PLUG app should be implemented as these would result in a better understanding of all ground handling processes and a better TOBT prediction.

Amsterdam Airport Schiphol (AAS) plans the gate schedule at their gate planning department, with help of the LVNL and KLM an efficient as possible gate planning is made using scheduled arrival and departure times. During daily operations however, only very few flights arrive and depart exactly according to schedule as seen in the quantitative analysis. Therefore, a predicted arrival and departure time should be implemented which keeps in mind the historic arrival and departure times, weather and amount of passengers. These predicted times would be a lot closer to reality, resulting in a more robust planning.

The role of the KLM flight coordinator is not completely uncontroversial but is of great value to the gate planning department by exchanging information quickly. Other airlines should also be part of this cooperation as better communication between all airlines and the gate planning department would result in a more efficient gate planning. An example is a long-haul aircraft departing towards Schiphol. If this aircraft would share the expected arrival time with the gate planning department, changes could be made upfront instead of when the aircraft already arrived at the airport. Also the effect of last-minute gate changes should be researched, these last-minute changes may lead to late arriving passengers, offloading of bags and longer turnaround times.

As seen in the quantitative analysis the turnaround time delay does not differ much between airline business models. However, between base and non-base carriers the difference is significant. A solution is to implement landing/take-off charges incentives, related to turnaround time abiding. Further research is needed to see what the theoretical effects are on Schiphol gate capacity of this measure.

Air Traffic Control has a performing role in the gate process, the ground controllers have to accommodate all scheduled traffic. The implementation of local A-CDM has already helped the outbound planner as departing aircraft now have a Target Start-up Approval Time (TSAT). This TSAT is given based on a wide range of factors like which runway configuration is in use, what the weather is and which slot the aircraft has. At the moment some aircraft have to wait for their TSAT at the gate, spending more time at the gate. Research must prove how much this exactly happens and what would be possible solutions for this problem.

In short, there are five recommendations:

- Implement predicted EIBT and TOBT in gate planning system.
- Expand the role of the KLM flight coordinator by involving more airlines.
- Research effect of last-minute gate changes.
- Research exact impact of personnel shortage at ground handlers.
- Implement innovative solutions like the PLUG app for more information during aircraft turnaround and better TOBT prediction.

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Appendix I *Reflection*

During my graduation at the KDC Mainport Schiphol I learned new aspects of project management, research methods and corporate communication. The reflection is divided into four items of which I think I learned most of during graduating and are all described using the STARR method (Situation, Task, Action, Result and Reflection).

Primary and secondary research skills

Three main sources have been used during the research: literature research, quantitative analysis and interviews. Primary research skills were needed to analyse all this data and narrow it down to a conclusion.

Situation

When starting the quantitative analysis an A-CDM dataset of the LVNL was used to calculate scheduled and actual turnaround times of all flights in the month of July 2017. After analysing this dataset it was determined that the LVNL data did not contain a scheduled in-block time, causing the scheduled turnaround time to be incorrect. Later in the research period the timeframe was expanded to the complete summer season of 2017 including Schiphol data for the scheduled in-block time. Furthermore, interviews were conducted to validate the quantitative data results.

Task

Processing large quantities of data has not been learned during previous educations, this aspect therefore was very new. The data consisted of a total of almost 300,000 lines with a range of information about flight, airline and turnaround time. Predefined categorizations were needed to classify all flight movements according airline business models, type of aircraft, flight duration, etc.

The interviews were a completely new part of research that I never used before. Initially I thought that it would be hard to find people that had time and were willing to answer questions. However, I was positively surprised as most people I contacted agreed to meet and answer questions about the gate capacity at Schiphol airport.

Action

The predefined categorizations helped to classify the quantitative data accordingly. Using VBA codes the scheduled and actual turnaround times were calculated of all flight movements. The knowledge gained during second year courses Modelling & Simulation helped me to complete these codes. The interviews were conducted on multiple locations as the interviewee was always asked what was best for them. The questions were predefined however interviewees were given the freedom to speak freely about the subject. During the conversations all answers were written down in catchwords, when all interviews were finished all catchwords were combined and converted to a text piece. Before publishing the interviews, all interviewees have been asked for their consent and whether their answers were translated in a correct way.

Result

Using the Spotfire data visualization tool I was able to process all data and visualize it in the graphs found in this report. This tool turned out to be very useful as this program can filter the categorizations easily. Four out of six interviewees agreed to show their name in this report.

Reflection

I very much enjoyed working on the data analysis as I learned a lot about the turnaround process at Schiphol airport and was able to visualize the results in a clear graph. Also, I enjoyed conducting and processing the interviews as they contained some new views on the gate capacity at Schiphol airport that were not yet known by me.

SCRUM/Sprint review

When performing a research, effective communication with the customer is vital to make sure the research is conducted according to their wishes. Especially when performing a research for KDC Mainport this is important as it has three major stakeholders being the LVNL, AAS and KLM. This communication is established by SCRUM meetings and sprint reviews.

Situation

To have a good overview of the research a SCRUM board is used. This board contains the following categories: Task, to-do, doing and finished. Post-it's are used to write research tasks on and attach the note to a category. This system enabled me to perform one task at a time and know what had already been done and what still has to be done. Every Monday and Thursday our scrum master discussed the scrum board with us and asked whether we needed help with any of the tasks. Furthermore the bi-weekly sprint reviews with KDC-managers of the LVNL, AAS and KLM helped to stay in line with the KDC Mainport objectives.

Task

The scrum board was discussed twice a week, max 5 minutes, and had to be updated when discussed. This means almost every day new post-it's were added or put in the 'finished' category. For the sprint reviews the task was to have a max 5 minute presentation followed by 5 minutes of feedback.

Action

The scrum board had to be updated every day because it was discussed twice a week. Especially when determining the research scope the scrum board turned out to be useful to be focussed on the important aspects of the research. For the sprint reviews a new PowerPoint presentation was made and practiced included a maximum of three or four slides. These slides contained what I did since the previous sprint review and what I planned to do for the next two weeks. New research findings were presented every sprint to keep the managers up to date and to gain their feedback about all results.

Result

The scrum board really helped me to stay focused on the research and keep doing what should be done at a specific moment. Also the scrum sessions helped me to gain new opinions on the research as both the scrum master and other students provided feedback during those sessions. All feedback gained during sprint reviews was very helpful for the research as it helped to for example better visualize all results. Furthermore I developed excellent presenting skills as I had to be concise while still talking about my complete research progress.

Reflection

Effective communication was established by the SCRUM sessions and sprint reviews. These helped me to stay focussed on the research while the feedback helped the research to be even more applicable and deeper into the subject. Also it was interesting to be part of the LVNL, AAS and KLM cooperation, especially to be close to the relationship between these three companies.

Overall reflection

Overall I gained much experience during this research as I was able to be part of the KDC Centre of Excellence. Together with all five other students we were able to help each other's researches to a higher level. In the future I will be able to apply all gained skills, probably even next year as I will start my Master degree at the Amsterdam campus of Northumbria University.

Appendix II Airline categorization structure

The figure below shows an example of how all airlines at Schiphol airport have been categorized. The results can be found in appendix X.

64	Airline	Callsign (Acid)	Business model 1	BM 2	Base?	Ground Handler	Longhaul	Mediumhaul	Shorthaul	Widebody	Narrowbody	Schengen	Non-Schengen
65	Icelandair	ICE	FSNC			Swissport		x		x	x	x	
66	Iran Air	IRA	FSNC			Swissport	x			x			x
67	Jet Airways	JAI	FSNC			KLM	x			x			x
68	Jet2.com	EXS	LCC	Holiday		Menzies			x		x		x
69	Kalitta Air	CKS	Freighter			Menzies							
70	Kenya Airways	KQA	FSNC			KLM	x			x			x
71	KLM Cityhopper	KLM	FSNC	Regional	Base	KLM		x	x		x	x	x
	KLM Royal Dutch	KLM											
72	Airlines		FSNC	Freighter	Base	KLM	x	x	x	x	x	x	x
73	Korean Air	KAL	FSNC	Freighter		KLM	x			x			x
74	LAN Cargo	LOCO	Freighter							x			
	LOT Polish Airlines	LOT						x	x		x	x	
75	Airlines		FSNC			Aviapartner					x		
76	Lufthansa	DLH	FSNC			Aviapartner			x		x	x	
77	Martinair	MPH	Freighter		Base	KLM				x			
	MNG Airlines	MNB											
78	Cargo		Freighter			Menzies							
	Nippon Cargo Airlines	NCA								x			
79	Norwegian Air International	IBK	Freighter										
80	Norwegian Air International	IBK	Hybrid			Menzies	x	x	x	x	x	x	x

Appendix III LVNL dataset structure

The figure below shows an example of the LVNL dataset, a total of 290,000 lines made up the flight movements at Schiphol during summer season 2017.

1	time	acid	reg	ade	des	actg	wi	eobt_time	SIBT_time	atd_time	ata_time	aobt_time	sibt_time	depG	arrGnr	l
103125	13-6-2017 7:30	KLM45C	PHEBGL	EHAM	EDDM	B737	M	13-6-2017 7:15	1-1-1970 1:00	13-6-2017 7:30	1-1-1970 1:00	13-6-2017 7:21	1-1-1970 1:00	D44		
103126	13-6-2017 7:30	KLM1332	PHEZK	EKYT	EHAM	E190	M	13-6-2017 6:30	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:30	1-1-1970 1:00	13-6-2017 7:34	A54		
103127	13-6-2017 7:31	EZY65GB	GEZPE	EHAM	LICC	A320	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:31	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	H05		
103128	13-6-2017 7:32	AUA378S	DELBU	EHAM	LOWW	A320	M	13-6-2017 7:00	1-1-1970 1:00	13-6-2017 7:32	1-1-1970 1:00	13-6-2017 7:21	1-1-1970 1:00	B15		
103129	13-6-2017 7:33	KLM74L	PHBXW	ESGG	EHAM	B738	M	13-6-2017 6:10	13-6-2017 7:40	1-1-1970 1:00	13-6-2017 7:33	1-1-1970 1:00	13-6-2017 7:40	D48		
103130	13-6-2017 7:34	TRA51Q	PHHSI	EHAM	LFFR	B738	M	13-6-2017 7:05	1-1-1970 1:00	13-6-2017 7:34	1-1-1970 1:00	13-6-2017 7:23	1-1-1970 1:00	C16		
103131	13-6-2017 7:34	KLM84X	PHKZL	LFSB	EHAM	F70	M	13-6-2017 6:20	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:34	1-1-1970 1:00	13-6-2017 7:45	E76		
103132	13-6-2017 7:35	KLM73H	PHBFH	EHAM	TNCC	B744	H	13-6-2017 10:00	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	F05		
103133	13-6-2017 7:35	KLM1382	PHBKK	EHAM	UKBB	B738	M	13-6-2017 4:45	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 7:46	D23		
103134	13-6-2017 7:35	N625SC	N625SC	KTEB	EHAM	GL5T	M	13-6-2017 1:00	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 7:40	GL		
103135	13-6-2017 7:35	AZA11A	EIJMJ	EHAM	LIRF	A319	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:35	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	C10		
103136	13-6-2017 7:36	KLM678	PHAKD	CYYC	EHAM	A333	H	12-6-2017 23:10	13-6-2017 8:05	1-1-1970 1:00	13-6-2017 7:36	1-1-1970 1:00	13-6-2017 7:51	E77		
103137	13-6-2017 7:37	KLM82G	PHEZY	ENTO	EHAM	E190	M	13-6-2017 6:20	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:37	1-1-1970 1:00	13-6-2017 7:44	B24		
103138	13-6-2017 7:38	EZY89FR	GEZAG	EHAM	LIRF	A319	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:38	1-1-1970 1:00	13-6-2017 7:25	1-1-1970 1:00	H06		
103139	13-6-2017 7:40	LLX9026	DABDB	EHAM	LGTS	A320	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:40	1-1-1970 1:00	13-6-2017 7:30	1-1-1970 1:00	D95		
103140	13-6-2017 7:40	KLM1178	PHEZI	ESSL	EHAM	E190	M	13-6-2017 6:10	13-6-2017 7:55	1-1-1970 1:00	13-6-2017 7:40	1-1-1970 1:00	1-1-1970 1:00	B20		
103141	13-6-2017 7:41	EZY43JA	GEZEV	EKKK	EHAM	A319	M	13-6-2017 6:55	13-6-2017 8:25	1-1-1970 1:00	13-6-2017 7:41	1-1-1970 1:00	13-6-2017 7:55	H05		
103142	13-6-2017 7:42	KLM19U	PHBXT	EHAM	LIRF	B739	M	13-6-2017 7:15	1-1-1970 1:00	13-6-2017 7:42	1-1-1970 1:00	13-6-2017 7:33	1-1-1970 1:00	D48		
103143	13-6-2017 7:43	EWG7180	DABGM	EDDH	EHAM	A319	M	13-6-2017 6:40	13-6-2017 7:40	1-1-1970 1:00	13-6-2017 7:43	1-1-1970 1:00	13-6-2017 7:52	B27		
103144	13-6-2017 7:44	ET1813Z	SEPLR	EHAM	LIRQ	C56X	M	13-6-2017 7:30	1-1-1970 1:00	13-6-2017 7:43	1-1-1970 1:00	13-6-2017 7:39	1-1-1970 1:00	GD		
103145	13-6-2017 7:44	TF1454	PHFTD	GBYD	EHAM	B738	M	13-6-2017 1:40	13-6-2017 7:25	1-1-1970 1:00	13-6-2017 7:44	1-1-1970 1:00	13-6-2017 7:58	G04		
103146	13-6-2017 7:45	CA1020	TCTJS	EHAM	LTBS	B738	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:45	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	G04		
103147	13-6-2017 7:45	KLM1350	PHBGI	LKPR	EHAM	B737	M	13-6-2017 6:30	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 7:45	1-1-1970 1:00	13-6-2017 7:52	C05		
103148	13-6-2017 7:46	VLG83LY	ECLUN	EHAM	LEBL	A320	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:46	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	B35		
103149	13-6-2017 7:46	KLM38H	PHADC	MUHA	EHAM	A332	H	12-6-2017 22:35	13-6-2017 8:05	1-1-1970 1:00	13-6-2017 7:46	1-1-1970 1:00	13-6-2017 8:00	G08		
103150	13-6-2017 7:47	KLM26B	PHEZD	LIFE	EHAM	E190	M	13-6-2017 6:00	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 7:47	1-1-1970 1:00	13-6-2017 7:51	A42		
103151	13-6-2017 7:47	EZY13UV	GEZBJ	EHAM	LHBP	A319	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:47	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	G71		
103152	13-6-2017 7:48	KLM79M	PHECA	EHAM	EKCH	B738	M	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 7:48	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	D41		
103153	13-6-2017 7:48	EZY95KC	GEZVP	LIMC	EHAM	A320	M	13-6-2017 6:20	13-6-2017 8:10	1-1-1970 1:00	13-6-2017 7:48	1-1-1970 1:00	13-6-2017 8:01	H02		
103154	13-6-2017 7:49	KLM52F	PHBCE	EPWA	EHAM	B738	M	13-6-2017 6:00	13-6-2017 7:55	1-1-1970 1:00	13-6-2017 7:49	1-1-1970 1:00	13-6-2017 7:55	B35		
103155	13-6-2017 7:50	KLM92Z	PHBXD	EGCC	EHAM	B738	M	13-6-2017 6:55	13-6-2017 8:20	1-1-1970 1:00	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 8:02	D12		
103156	13-6-2017 7:50	CND215	PHCDE	EHAM	LWOH	B738	M	13-6-2017 7:20	1-1-1970 1:00	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:39	1-1-1970 1:00	D14		
103157	13-6-2017 7:50	KLM1184	PHBXJ	ENBR	EHAM	B738	M	13-6-2017 6:30	13-6-2017 8:10	1-1-1970 1:00	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:56	C18		
103158	13-6-2017 7:51	TRA53A	PHHXE	EHAM	LEAM	B738	M	13-6-2017 7:25	1-1-1970 1:00	13-6-2017 7:51	1-1-1970 1:00	13-6-2017 7:40	1-1-1970 1:00	D52		
103159	13-6-2017 7:51	DAL160	N807NW	KMSP	EHAM	A333	H	13-6-2017 0:04	13-6-2017 8:30	1-1-1970 1:00	13-6-2017 7:51	1-1-1970 1:00	13-6-2017 8:07	E05		
103160	13-6-2017 7:52	EZY28PV	GEZOD	EHAM	LDSF	A320	M	13-6-2017 7:45	1-1-1970 1:00	13-6-2017 7:52	1-1-1970 1:00	13-6-2017 7:40	1-1-1970 1:00	H04		
103161	13-6-2017 7:53	EZY104Z	GEZMH	EHAM	LFSB	A319	M	13-6-2017 7:25	1-1-1970 1:00	13-6-2017 7:53	1-1-1970 1:00	13-6-2017 7:41	1-1-1970 1:00	H01		
103162	13-6-2017 7:53	KLM1762	PHEZK	EDDF	EHAM	E190	M	13-6-2017 7:00	13-6-2017 8:10	1-1-1970 1:00	13-6-2017 7:53	1-1-1970 1:00	13-6-2017 7:58	B32		
103163	13-6-2017 7:53	KLM24V	PHBGG	LFB0	EHAM	B737	M	13-6-2017 6:30	13-6-2017 8:10	1-1-1970 1:00	13-6-2017 7:53	1-1-1970 1:00	13-6-2017 8:06	C10		
103164	13-6-2017 7:55	KLM38H	PHEZF	LIPZ	EHAM	E190	M	13-6-2017 6:00	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 7:55	1-1-1970 1:00	13-6-2017 8:05	A34		
103165	13-6-2017 7:55	BAW423	GEUPC	EHAM	EGLL	A319	M	13-6-2017 7:45	1-1-1970 1:00	13-6-2017 7:55	1-1-1970 1:00	13-6-2017 7:44	1-1-1970 1:00	D28		
103166	13-6-2017 7:56	EZY17XL	GEZUG	EGGW	EHAM	A320	M	13-6-2017 7:00	13-6-2017 8:15	1-1-1970 1:00	13-6-2017 7:56	1-1-1970 1:00	13-6-2017 8:08	H04		
103167	13-6-2017 7:56	JAI234	VTJES	VIDP	EHAM	B77W	H	12-6-2017 23:05	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 7:56	1-1-1970 1:00	13-6-2017 8:02	G09		
103168	13-6-2017 7:56	KLM1153	PHBXH	EHAM	ESGG	E170	M	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 7:56	1-1-1970 1:00	13-6-2017 7:49	1-1-1970 1:00	B85		
103169	13-6-2017 7:57	KLM933	PHBXJ	EHAM	EIDW	E170	M	13-6-2017 7:40	1-1-1970 1:00	13-6-2017 7:57	1-1-1970 1:00	13-6-2017 7:50	1-1-1970 1:00	B82		
103170	13-6-2017 7:58	KLM1502	PHKZM	EGSH	EHAM	F70	M	13-6-2017 7:15	13-6-2017 8:10	1-1-1970 1:00	13-6-2017 7:58	1-1-1970 1:00	13-6-2017 8:11	B82		
103171	13-6-2017 7:58	TRA805M	PHHSG	EHAM	LFKJ	B738	M	13-6-2017 7:40	1-1-1970 1:00	13-6-2017 7:58	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	C18		
103172	13-6-2017 7:58	AFRI236	PHBXM	LFST	EHAM	E170	M	13-6-2017 6:50	13-6-2017 8:05	1-1-1970 1:00	13-6-2017 7:58	1-1-1970 1:00	13-6-2017 8:05	B92		
103173	13-6-2017 7:59	TF1217	PHFTA	EHAM	LGSM	B738	M	13-6-2017 7:45	1-1-1970 1:00	13-6-2017 7:59	1-1-1970 1:00	13-6-2017 7:50	1-1-1970 1:00	D12		
103174	13-6-2017 8:00	DAL126	N814MW	KBOS	EHAM	A333	H	13-6-2017 0:40	13-6-2017 7:50	1-1-1970 1:00	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 8:16	D43		
103175	13-6-2017 8:00	ABW251	VQBRH	UUEE	EHAM	B748	H	13-6-2017 4:40	13-6-2017 8:15	1-1-1970 1:00	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 8:08	S79		
103176	13-6-2017 8:01	TF1441	PHFTF	EHAM	GVBA	B738	M	13-6-2017 7:35	1-1-1970 1:00	13-6-2017 8:01	1-1-1970 1:00	1-1-1970 1:00	1-1-1970 1:00	G02		
103177	13-6-2017 8:01	DAL178	N823NW	KPDX	EHAM	A333	H	12-6-2017 22:26	13-6-2017 8:30	1-1-1970 1:00	13-6-2017 8:01	1-1-1970 1:00	13-6-2017 8:18	E72		
103178	13-6-2017 8:02	KLM1471	PHBGP	EHAM	EGPF	B737	M	13-6-2017 8:00	1-1-1970 1:00	13-6-2017 8:02	1-1-1970 1:00	13-6-2017 7:53	1-1-1970 1:00	D56		
103179	13-6-2017 8:02	KLM70X	PHBXN	ENVA	EHAM	E170	M	13-6-2017 6:00	13-6-2017							

Appendix IV Schiphol dataset structure

The figure below shows an example of the Schiphol dataset, a total of 166,000 lines made up the flight movements during summer season 2017.

1	ARRDATE	SIBT	FLTNR	CALLSIGN	Kolom1	ACREG	ACTYP	AIRLINE	HANDLER_PAX	Datum
23	26-3-2017 0:00	26-3-2017 6:00	DL0046	DAL46	DAL	N181DN	B763	Delta Airlines	KLM	26-3-2017
24	26-3-2017 0:00	26-3-2017 6:20	KL0576	KLM576	KLM	PHAOB	A332	KLM	KLM	26-3-2017
25	26-3-2017 0:00	26-3-2017 6:20	KL0432	KLM432	KLM	PHAOD	A332	KLM	KLM	26-3-2017
26	26-3-2017 0:00	26-3-2017 6:20	CZ451	CSN451	CSN	B2073	B77L	China Southern Airlines	KLM	26-3-2017
27	26-3-2017 0:00	26-3-2017 6:40	CX271	CPA271	CPA	BKQB	B77W	Cathay Pacific	Swissport	26-3-2017
28	26-3-2017 0:00	26-3-2017 6:40	EK9749	UAE9749	UAE	A6EFO	B77L	Emirates	Swissport	26-3-2017
29	26-3-2017 0:00	26-3-2017 6:45	KL0588	KLM588	KLM	PHBQN	B772	KLM	KLM	26-3-2017
30	26-3-2017 0:00	26-3-2017 6:55	KL0810	KLM810	KLM	PHBVA	B77W	KLM	KLM	26-3-2017
31	26-3-2017 0:00	26-3-2017 6:55	MU0771	CES771	CES	B5936	A332	China Eastern Airlines	KLM	26-3-2017
32	26-3-2017 0:00	26-3-2017 6:55	KL0590	KLM590	KLM	PHBQC	B772	KLM	KLM	26-3-2017
33	26-3-2017 0:00	26-3-2017 6:55	CZ0307	CSN307	CSN	B6135	A332	China Southern Airlines	KLM	26-3-2017
34	26-3-2017 0:00	26-3-2017 7:00	KL0537	KLM538	KLM	PHAOM	A332	KLM	KLM	26-3-2017
35	26-3-2017 0:00	26-3-2017 7:00	KL1720	KLM1720	KLM	PHKZK	F70	KLM	KLM	26-3-2017
36	26-3-2017 0:00	26-3-2017 7:00	KL0624	KLM254	KLM	PHBQE	B772	KLM	KLM	26-3-2017
37	26-3-2017 0:00	26-3-2017 7:15	UA946	UAL946	UAL	N76054	B764	United Airlines	Aviapartner	26-3-2017
38	26-3-2017 0:00	26-3-2017 7:15	SQ324	SIA324	SIA	9VSMK	A359	Singapore Airlines	Swissport	26-3-2017
39	26-3-2017 0:00	26-3-2017 7:15	KL0428	KLM428	KLM	PHBQL	B772	KLM	KLM	26-3-2017
40	26-3-2017 0:00	26-3-2017 7:20	KL1900	KLM26M	KLM	PHKZP	F70	KLM	KLM	26-3-2017
41	26-3-2017 0:00	26-3-2017 7:20	KL1880	KLM60K	KLM	PHEZZ	E190	KLM	KLM	26-3-2017
42	26-3-2017 0:00	26-3-2017 7:20	KL1852	KLM34Z	KLM	PHKZB	F70	KLM	KLM	26-3-2017
43	26-3-2017 0:00	26-3-2017 7:20	KL1776	KLM88J	KLM	PHBGP	B737	KLM	KLM	26-3-2017
44	26-3-2017 0:00	26-3-2017 7:20	KL1340	KLM28K	KLM	PHBGO	B737	KLM	KLM	26-3-2017
45	26-3-2017 0:00	26-3-2017 7:20	KL1818	KLM22T	KLM	PHBXI	B738	KLM	KLM	26-3-2017
46	26-3-2017 0:00	26-3-2017 7:20	KL1750	KLM62N	KLM	PHEXI	E170	KLM	KLM	26-3-2017
47	26-3-2017 0:00	26-3-2017 7:25	KL1124	KLM1124	KLM	PHBGR	B737	KLM	KLM	26-3-2017
48	26-3-2017 0:00	26-3-2017 7:25	KL0415	KLM415	KLM	PHAKD	A333	KLM	KLM	26-3-2017
49	26-3-2017 0:00	26-3-2017 7:25	KL1866	KLM42A	KLM	PHEZY	E190	KLM	KLM	26-3-2017
50	26-3-2017 0:00	26-3-2017 7:30	KL1196	KLM1196	KLM	PHEZX	E190	KLM	KLM	26-3-2017
51	26-3-2017 0:00	26-3-2017 7:30	DL0126	DAL126	DAL	N827NW	A333	Delta Airlines	KLM	26-3-2017
52	26-3-2017 0:00	26-3-2017 7:30	KL0566	KLM566	KLM	PHBFG	B744	KLM	KLM	26-3-2017
53	26-3-2017 0:00	26-3-2017 7:35	UA070	UAL70	UAL	N17126	B752	United Airlines	Aviapartner	26-3-2017
54	26-3-2017 0:00	26-3-2017 7:35	KL1382	KLM1382	KLM	PHBXV	B738	KLM	KLM	26-3-2017
55	26-3-2017 0:00	26-3-2017 7:40	KL0933F	KLM933	KLM	PHEZT	E190	KLM	KLM	26-3-2017
56	26-3-2017 0:00	26-3-2017 7:40	Y87455	YZR7455	YZR	B2435	B744	Yangtze River Airlines Co.Ltd	KLM	26-3-2017
57	26-3-2017 0:00	26-3-2017 7:40	KL0450	KLM450	KLM	PHBHI	B789	KLM	KLM	26-3-2017
...

Appendix V Data results structure

The figure below shows an example of final dataset used for the research, a total of 290,000 lines made up the flight movements at Schiphol during summer season 2017.

S	I	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
Datum	A/D	AOE	SOB	ATA	STI	Airline E	Fligh	Base car	NABO/Wil	Diff A-S	Ground handle	RECAT-EU	Pier
13-6-2017	Departure					FSNC	Short	Base	Narrow		KLM	D	
13-6-2017	Arrival	8:50	8:40	76	50	FSNC	Short	Base	Narrow	26	KLM	E	A
13-6-2017	Departure					LCC	Medium	Base	Narrow		Menzies	D	
13-6-2017	Departure					FSNC	Short	Base	Narrow		Aviapartner	D	
13-6-2017	Arrival	8:47	8:40	67	60	FSNC	Medium	Base	Narrow	7	KLM	D	D
13-6-2017	Departure					LCC	Medium	Base	Narrow		KLM	D	
13-6-2017	Arrival	8:36	8:35	51	45	FSNC	Short	Base	Narrow	6	KLM	E	B
13-6-2017	Departure					FSNC	Long	Base	Wide		KLM	B	
13-6-2017	Arrival	8:42	8:30	56	55	FSNC	Medium	Base	Narrow	1	KLM	D	D
13-6-2017	Arrival	14:35	9:30	415	115		Long			300			G
13-6-2017	Departure					FSNC	Medium		Narrow		KLM	D	
13-6-2017	Arrival	14:42	14:30	411	385	FSNC	Long	Base	Wide	26	KLM	B	E
13-6-2017	Arrival	8:39	8:25	55	35	FSNC	Short	Base	Narrow	20	KLM	E	B
13-6-2017	Departure					LCC	Medium	Base	Narrow		Menzies	D	
13-6-2017	Departure					Holiday	Medium		Narrow		Menzies	D	
13-6-2017	Arrival	8:30	8:30	2,5E+07	35	FSNC	Medium	Base	Narrow	24955615	KLM	E	B
13-6-2017	Arrival	14:23	12:40	388	255	LCC	Short	Base	Narrow	133	Menzies	D	H
13-6-2017	Departure					FSNC	Medium	Base	Narrow		KLM	D	
13-6-2017	Arrival	8:27	8:15	35	35	LCC	Short		Narrow	0	Menzies	D	B
13-6-2017	Departure						Medium						
13-6-2017	Arrival	9:17	9:01	79	96	Holiday	Medium	Base	Narrow	-17	Swissport	D	G
13-6-2017	Departure					Holiday	Medium		Narrow		Swissport	D	
13-6-2017	Arrival	8:49	8:45	57	45	FSNC	Short	Base	Narrow	12	KLM	D	C
13-6-2017	Departure					LCC	Medium		Narrow		Aviapartner	D	
13-6-2017	Arrival	14:08	10:15	368	130	FSNC	Long	Base	Wide	238	KLM	B	G
13-6-2017	Arrival	8:53	8:45	62	45	FSNC	Medium	Base	Narrow	17	KLM	E	A
13-6-2017	Departure					LCC	Medium	Base	Narrow		Menzies	D	
13-6-2017	Departure					FSNC	Short	Base	Narrow		KLM	D	
13-6-2017	Arrival	8:34	8:40	33	30	LCC	Medium	Base	Narrow	3	Menzies	D	H
13-6-2017	Arrival	9:04	8:45	69	50	FSNC	Medium	Base	Narrow	19	KLM	D	B
13-6-2017	Arrival	9:08	9:10	66	50	FSNC	Short	Base	Narrow	16	KLM	D	D
13-6-2017	Departure					Holiday	Medium	Base	Narrow		Swissport	D	
13-6-2017	Arrival	9:17	9:05	81	55	FSNC	Short	Base	Narrow	26	KLM	D	C
13-6-2017	Departure					LCC	Medium	Base	Narrow		KLM	D	
13-6-2017	Arrival	13:09	10:35	302	125	FSNC	Long	Base	Wide	177	KLM	B	E
13-6-2017	Departure					LCC	Medium	Base	Narrow		Menzies	D	
13-6-2017	Departure					LCC	Short	Base	Narrow		Menzies	D	
13-6-2017	Arrival	8:51	8:45	53	35	FSNC	Short	Base	Narrow	18	KLM	E	B
13-6-2017	Arrival	9:23	9:20	77	70	FSNC	Short	Base	Narrow	7	KLM	D	C
13-6-2017	Arrival	8:39	8:35	34	35	FSNC	Medium	Base	Narrow	-1	KLM	E	A
13-6-2017	Departure					FSNC	Short		Narrow		Aviapartner	D	
13-6-2017	Arrival	19:02	8:45	654	30	LCC	Short	Base	Narrow	624	Menzies	D	H
13-6-2017	Arrival	11:46	11:25	224	205	FSNC	Long		Wide	19	KLM	B	G
13-6-2017	Departure					FSNC	Medium	Base	Narrow		KLM	E	
13-6-2017	Departure					FSNC	Short	Base	Narrow		KLM	E	
13-6-2017	Arrival	9:10	9:10	59	60	FSNC	Short	Base	Narrow	-1	KLM	E	B
13-6-2017	Departure					LCC	Short	Base	Narrow		KLM	D	
13-6-2017	Arrival	10:06	10:00	121	115	FSNC	Short		Narrow	6	KLM	E	B
13-6-2017	Departure					Holiday	Medium	Base	Narrow		Swissport	D	
13-6-2017	Arrival	13:06	13:00	290	310	FSNC	Long	Base	Wide	-20	KLM	B	D
13-6-2017	Arrival	14:42	11:20	394	185	Freighter	Medium		Wide	209		B	S
13-6-2017	Departure					Holiday	Medium	Base	Narrow		Swissport	D	
13-6-2017	Arrival	10:55	10:35	157	125	FSNC	Long	Base	Wide	32	KLM	B	E
13-6-2017	Departure					FSNC	Short	Base	Narrow		KLM	D	
13-6-2017	Arrival	8:58	9:00	51	45	FSNC	Short	Base	Narrow	6	KLM	E	B
13-6-2017	Arrival	10:48	9:25	154	70	FSNC	Short	Base	Narrow	84	KLM	E	A
13-6-2017	Departure					LCC	Short	Base	Narrow		Menzies	D	
13-6-2017	Arrival	9:30	9:25	82	65	FSNC	Short	Base	Narrow	17	KLM	E	A
13-6-2017	Arrival	9:05	9:00	50	45	FSNC	Medium	Base	Narrow	5	KLM	E	B
13-6-2017	Departure					FSNC	Short	Base	Narrow		KLM	D	

Appendix VI ***Ethical considerations***

The ethical guidelines of nine professional social sciences research associations:

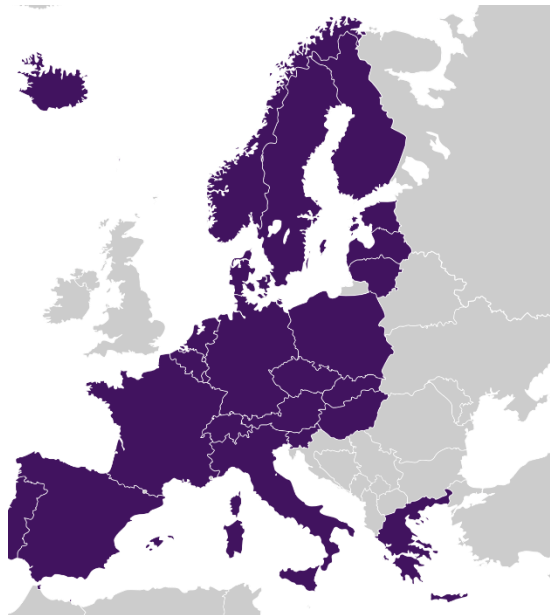
1. Research participants should not be subjected to harm in any ways whatsoever.
2. Respect for the dignity of research participants should be prioritized.
3. Full consent should be obtained from the participants prior to the study.
4. The protection of the privacy of research participants has to be ensured.
5. Adequate level of confidentiality of the research data should be ensured.
6. Anonymity of individuals and organizations participating in the research has to be ensured.
7. Any deception or exaggeration about the aims and objectives of the research must be avoided.
8. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests have to be declared.
9. Any type of communication in relation to the research should be done with honesty and transparency.
10. Any type of misleading information, as well as representation of primary data findings in a biased way must be avoided.

Appendix VII *Schengen destinations*

The Schengen area consists of:

- Belgium
- Denmark (excluding the Faroe Isles and Greenland)
- Germany (excluding Heligoland)
- Estonia
- Finland
- France (excluding French Guiana, Guadeloupe, Martinique, Mayotte and La Reunion)
- Greece
- Hungary
- Italy
- Latvia
- Liechtenstein
- Lithuania
- Luxembourg
- Malta
- The Netherlands
- Norway (excluding Spitsbergen)
- Austria
- Poland
- Portugal (including the Azores and Madeira)
- Slovenia
- Slovakia
- Spain (including the Balearic Islands and the Canary Islands)
- Czech Republic
- Iceland
- Sweden
- Switzerland

Visualization:



Appendix VIII Flight range distribution

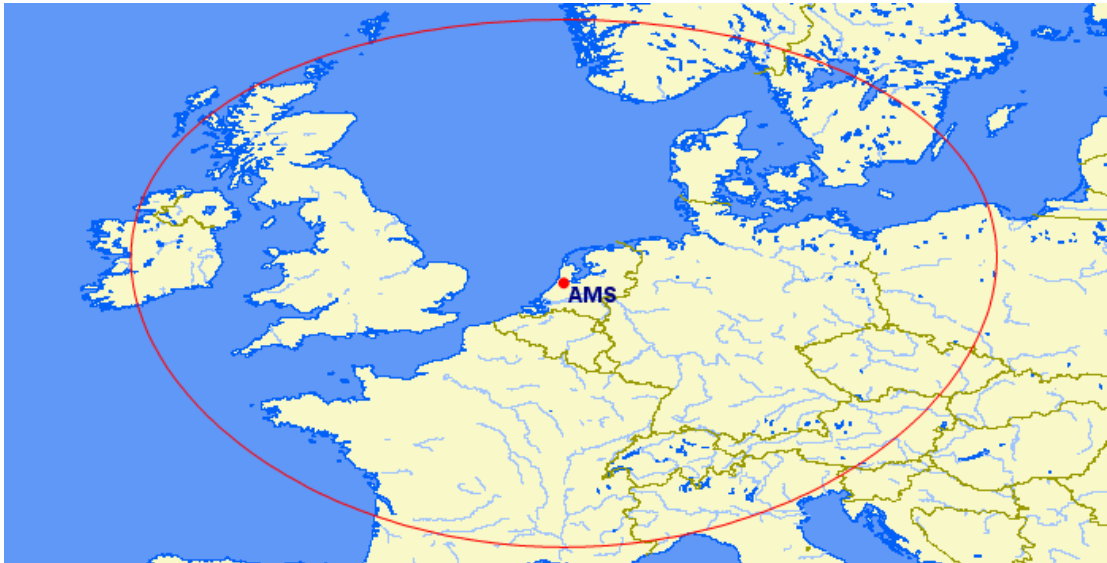


Figure 18, 500NM range from Schiphol (Great Circle Mapper, 2018).

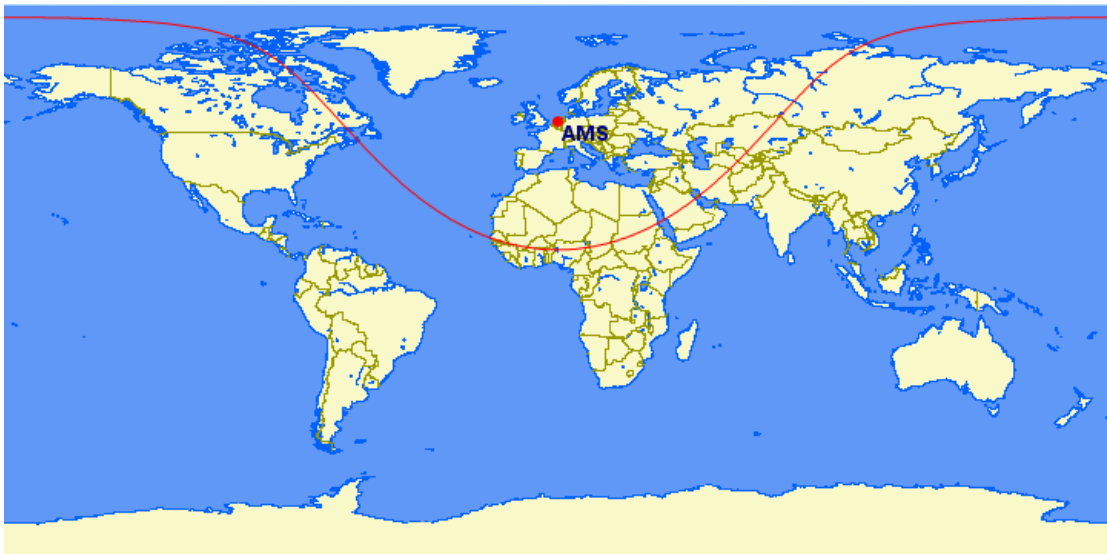


Figure 19, 2500NM range from Schiphol (Great Circle Mapper, 2018).

Destination categorization table in data:

Destinations	ICAO identification	Flight range
Afghanistan	OA	Medium
Albania	LA	Medium
Armenia	UD	Medium
Austria	LO	Short
Azerbaijan	UB	Medium
Bahrain	OB	Medium
Belarus and Russia (Kaliningrad Oblast)	UM	Medium
Belgium	EB	Short
Bosnia and Herzegovina	LQ	Medium
Bulgaria	LB	Medium

Cape Verde	GV	Medium
Croatia	LD	Medium
Cyprus	LC	Medium
Czech	LK	Short
Denmark	EK	Short
Egypt	HE	Medium
Estonia	EE	Medium
Finland	EF	Medium
France	LF	Short
Georgia	UG	Medium
Germany	ED	Short
Gibraltar	LX	Medium
Greece	LG	Medium
Guinea	GU	Medium
Guinea-Bissau	GG	Medium
Hungary	LH	Medium
Iceland	BI	Medium
Iran	OI	Medium
Iraq	OR	Medium
Ireland	EI	Short
Israel	LL	Medium
Italy	LI	Medium
Italy North	LIM	Short
Jordan and the West Bank	OJ	Medium
Kazakhstan	UA	Medium
Kuwait	OK	Medium
Kyrgyzstan	UC	Medium
Latvia	EV	Medium
Lebanon	OL	Medium
Liberia	GL	Medium
Lithuania	EY	Medium
Luxembourg	EL	Short
Macedonia	LW	Medium
Malta	LM	Medium
Mauritania	GQ	Medium
Moldova	LU	Medium
Monaco	LN	Medium
Morocco	GM	Medium
Netherlands	EH	
Norway	EN	Short
Palestinian territories	LV	Medium
Poland	EP	Medium
Portugal (including the Azores and Madeira)	LP	Medium
Romania	LR	Medium
Russia	UL	Medium

Russia	UU	Medium
Saudi Arabia	OE	Medium
Senegal	GO	Medium
Serbia and Montenegro	LY	Medium
Sierra Leone	GF	Medium
Slovakia	LZ	Medium
Slovenia	LJ	Medium
Spain (Canary Islands)	GC	Medium
Spain (Ceuta and Melilla)	GE	Medium
Spain (mainland section and Balearic Islands)	LE	Medium
Sweden	ES	Medium
Switzerland	LS	Short
Syria	OS	Medium
Tajikistan, Turkmenistan, Uzbekistan	UT	Medium
The Gambia	GB	Medium
Turkey	LT	Medium
UK	EG	Short
Ukraine	UK	Medium
Western Sahara	GS	Medium

Appendix IX EU wake turbulence categorisation and separation minima

Table 12, aircraft types assigned to RECAT-EU categories (Eurocontrol, 2015).

'SUPER HEAVY'	'UPPER HEAVY'	'LOWER HEAVY'	'UPPER MEDIUM'	'LOWER MEDIUM'	'LIGHT'
'CAT-A'	'CAT-B'	'CAT-C'	'CAT-D'	'CAT-E'	'CAT-F'
A388	A332	A306	A318	AT43	FA10
A124	A333	A30B	A319	AT45	FA20
(...)	A343	A310	A320	AT72	D328
	A345	B703	A321	B712	E120
	A346	B752	AN12	B732	BE40
	A359	B753	B736	B733	BE45
	B744	B762	B737	B734	H25B
	B748	B763	B738	B735	JS32
	B772	B764	B739	CL60	JS41
	B773	B783	C130	CRJ1	LJ35
	B77L	C135	IL18	CRJ2	LJ60
	B77W	DC10	MD81	CRJ7	SF34
	B788	DC85	MD82	CRJ9	P180
	B789	IL76	MD83	DH8D	C650
	IL96	MD11	MD87	E135	C525
	(...)	TU22	MD88	E145	C180
		TU95	MD90	E170	C152
		(...)	T204	E175	(...)
			TU16	E190	
			(...)	E195	
				F70	
				F100	
				GLF4	
				RJ85	
				RJ1H	
				(...)	

Table 13, RECAT-EU separation minima on approach and departure (Eurocontrol, 2015).

RECAT-EU scheme		"SUPER HEAVY"	"UPPER HEAVY"	"LOWER HEAVY"	"UPPER MEDIUM"	"LOWER MEDIUM"	"LIGHT"
Leader / Follower		"A"	"B"	"C"	"D"	"E"	"F"
"SUPER HEAVY"	"A"	3 NM	4 NM	5 NM	5 NM	6 NM	8 NM
"UPPER HEAVY"	"B"		3 NM	4 NM	4 NM	5 NM	7 NM
"LOWER HEAVY"	"C"		(*)	3 NM	3 NM	4 NM	6 NM
"UPPER MEDIUM"	"D"						5 NM
"LOWER MEDIUM"	"E"						4 NM
"LIGHT"	"F"						3 NM

Wake turbulence categorization table in data:

Aircraft mix		
Aircraft	NABO/WIBO	EU categorisation
A20N	Narrow	D
A318	Narrow	D
A319	Narrow	D
A320	Narrow	D
A321	Narrow	D
AT72	Narrow	E
AT75	Narrow	E
B733	Narrow	E
B734	Narrow	E
B735	Narrow	E
B736	Narrow	D
B737	Narrow	D
B738	Narrow	D
B739	Narrow	D
B752	Narrow	C
B753	Narrow	C
BCS1	Narrow	D
BCS3	Narrow	D
CRJ2	Narrow	E
CRJ7	Narrow	E
CRJ9	Narrow	E
CRJX	Narrow	E
D228	Narrow	F
D328	Narrow	F
DH8D	Narrow	E
E120	Narrow	F
E145	Narrow	E
E170	Narrow	E
E175	Narrow	E
E190	Narrow	E
E195	Narrow	E
E75L	Narrow	E
F70	Narrow	E
F100	Narrow	E
J328	Narrow	F
MD83	Narrow	D
MD87	Narrow	D
RJ85	Narrow	E
RJ1H	Narrow	E
SB20	Narrow	E

SU95	Narrow	E
A306	Wide	C
A310	Wide	C
A332	Wide	B
A333	Wide	B
A343	Wide	B
A345	Wide	B
A346	Wide	B
A359	Wide	B
A388	Wide	A
B744	Wide	B
B748	Wide	B
B763	Wide	C
B764	Wide	C
B772	Wide	B
B773	Wide	B
B77L	Wide	B
B77W	Wide	B
B788	Wide	B
B789	Wide	B

**Appendix X
categorization**

Complete 2017 Schiphol airline

Airline	Business model	Ground handler	Airline	Business model	Ground Handler
Adria Airways	Regional	Swissport	China Southern Airlines	FSNC	KLM
Aegean Airlines	FSNC	Aviapartner	CityJet	Holiday	KLM
Aer Lingus	LCC	Aviapartner	Corendon Airlines	Holiday	Swissport
Aeroflot	FSNC	Menzies	Corendon Dutch Airlines	Holiday	Swissport
Aeromexico	FSNC	KLM	Coyne Airways	Freighter	
Atlas Air	Freighter	KLM	Croatia Airlines	FSNC	Aviapartner
Air Arabia Maroc	LCC	Aviapartner	CSA Czech Airlines	FSNC	Menzies
Air Astana	FSNC	Aviapartner	Delta Air Lines	FSNC	KLM
Air Canada	FSNC	Swissport	easyJet	LCC	Menzies
Air Europa Lineas Aereas	FSNC	KLM	easyjet Switzerland	LCC	Menzies
Air France	FSNC	KLM	EgyptAir	FSNC	Swissport
Air Malta	FSNC	Aviapartner	El Al	FSNC	Aviapartner
Air Serbia	FSNC	Swissport	Emirates Airline	FSNC	dnata Pax

Airline	Business model	Ground handler	Airline	Business model	Ground Handler
Air Transat	Holiday	Aviapartner	Etihad Airways	FSNC	Swissport
Air X charter	Holiday	Aviapartner Exec.	European air transport	Freighter	DHL
airBaltic	FSNC	Swissport	Eurowings	LCC	Menzies
AirBridgeCargo Airlines	Freighter		Eurowings	LCC	Menzies
Alitalia	FSNC	KLM	EVA Air	FSNC	Swissport
American Airlines	FSNC	Swissport	Evelop airlines	Holiday	Menzies
Arkia Israeli Airlines	LCC	Aviapartner	FedEx	Freighter	Menzies
AtlasGlobal	LCC	Aviapartner	Finnair	FSNC	Swissport
Austrian Airlines	FSNC	Aviapartner	Flybe	Regional	Swissport
Belavia	FSNC	KLM	Freebird airlines	Holiday	Aviapartner
BH air	Holiday	Swissport	Garuda Indonesia	FSNC	Swissport
British Airways	FSNC	Aviapartner	Georgian Airways	FSNC	KLM
British Airways Cityflyer	FSNC	Aviapartner	Iberia	FSNC	Aviapartner
Bulgaria Air	FSNC	Swissport	Airline	FSNC	Swissport
Cargolux Airlines International	Freighter		Icelandair	FSNC	Swissport
Cathay Pacific	FSNC	Swissport	Iran Air	FSNC	KLM
China Airlines	FSNC	KLM	Jet Airways	FSNC	Menzies
China Cargo Airlines	Freighter		Jet2.com	LCC	Menzies
China Eastern Airlines	FSNC	KLM	Kalitta Air	Freighter	Swissport

Airline	Business model 1	Ground handler	Airline	Business model 1	Ground handler
Kenya Airways	FSNC	KLM	Transavia	LCC	KLM
KLM Cityhopper	FSNC	KLM	Transavia France	LCC	KLM
KLM Royal Dutch Airlines	FSNC	KLM	Travel service	Holiday	Menzies
Korean Air	FSNC	KLM	TUI Airlines Netherlands	Holiday	Swissport
LAN Cargo	Freighter		Tunisair	FSNC	Aviapartner
LOT Polish Airlines	FSNC	Aviapartner	Turkish Airlines	FSNC	Aviapartner
Lufthansa	FSNC	Aviapartner	Ukraine International Airlines	FSNC	KLM
Martinair	Freighter	KLM	United Airlines	FSNC	Aviapartner
MNG Airlines Cargo	Freighter	Menzies	Vueling	LCC	Aviapartner
Nippon Cargo Airlines	Freighter		WOW air	LCC	Menzies
Norwegian Air International	Hybrid	Menzies	Xiamen Airlines	FSNC	KLM
Norwegian Air Shuttle ASA	Hybrid	Menzies	Yangtze River Express	Freighter	
Onur air	LCC	dnata Pax			
Pegasus Airlines	LCC	Aviapartner			
Qatar Airways	FSNC	Swissport			

Royal Air Maroc	FSNC	Aviapartner			
Airline	Business model 1	Ground handler	Airline	Business model 1	Ground handler
Royal Jordanian	FSNC	Swissport			
Ryanair	LCC	Menzies			
SAS	FSNC	Swissport			
Saudia	Freighter				
Silk Way West Airlines	Freighter				
Singapore Airlines	FSNC	Swissport			
Singapore Cargo	Freighter	Swissport			
SkyWork Airlines	Regional	Aviapartner			
Small Planet airlines	Holiday	Menzies			
SunExpress	LCC	Swissport			
SunExpress Deutschland	LCC	Swissport			
Suparna Airlines	Freighter				
Surinam Airways	FSNC	Aviapartner			
SWISS	FSNC	Aviapartner			
TAP Air Portugal	FSNC	Aviapartner			
TAROM	FSNC	KLM			

Appendix XI Aircraft stands at Schiphol airport

Simplified schematic table of all aircraft stands at platforms A through J.

Pier	Category	Amount	Remote/Pier
A	3	11	Remote
B	3	21	Remote
	4	7	Pier
	3	6	Pier
C	4	14	Pier
D	6	3	Pier
	7	6	Pier
	5	2	Pier
	4	21	Pier
	4	6	Remote
	8	1	Pier
E	7	4	Pier
	4	1	Pier
	8	8	Pier
	9	1	Pier
	7	1	Remote
	8	2	Remote
F	8	7	Pier
G	4	1	Pier
	8	6	Pier
	9	1	Pier
	4	1	Remote
	8	3	Remote
H	4	7	Pier
J	4	2	Remote
	9	1	Remote
	8	5	Remote
Subtotal	3	6	Pier
	3	32	Remote
	4	53	Pier
	4	7	Remote
	5	2	Pier
	6	3	Pier
	7	10	Pier
	7	1	Remote
	8	22	Pier
	8	10	Remote
	9	2	Pier
	9	1	Remote
Total		149	